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AN ELECTRON THEORY OF SOLIDS.*

BY

J. J. THOMSON, O.M., F.R.S.

Franklin Medalist, Honorary Member of the Institute.

My object in this paper is not so much to elaborate the details of a theory of solids as to point out that the electronic theory of the constitution of the atom leads quite simply and directly to a theory of solids which, as far as it has been tested, agrees remarkably well with the facts. I wish also to emphasize the point that the most convenient way of testing theories of the structure of the outer parts of the atom is by seeing the consequences they involve as to the properties of the elements when in the solid state. It sounds paradoxical, but it is true, that it may be less laborious to calculate the properties of practically an infinite number of atoms than of a single molecule with only two or three atoms.

The reason for this is very simple. Suppose we are considering a single molecule say of oxygen, as each atom of oxygen has six free electrons, we may regard the twelve electrons as distributed so that four are in the plane A bisecting at right angles the line joining the centres of the atoms. Another four are in a parallel plane B to the right of the two atoms, and another four in a plane C placed symmetrically on the left, with this distribution

* Presented at the Stated Meeting of the Institute held Wednesday, May 17, 1922.

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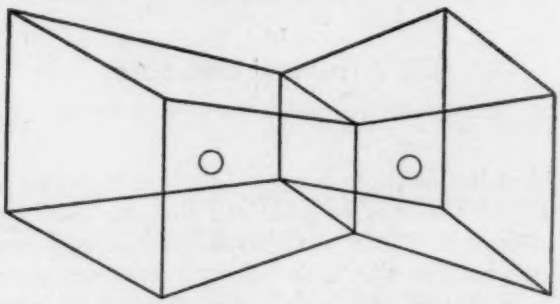
each oxygen atom may be regarded as surrounded by an octet of electrons.

Now the electrons in the plane *A* will be under different forces from those in the planes *B* and *C*. The result will be that the octets will not be cubes but figures like those in Fig. 1 whose geometry is somewhat complicated.

Now let us consider an oxygen atom in a solid crystal of oxygen, each atom will be surrounded by a symmetrical distribution of atoms and electrons and the arrangement of electrons round each atom will be quite symmetrical, so that these electrons

FIG. 1.



will be on a cube instead of on the camera-shaped figure shown in Fig. 1. It is true that in the solid we have in our calculations to take into account the influence of the large number of neighbors which each atom possesses, whereas in a single molecule each atom has but one neighbor, but as a matter of fact when the atoms are, as in a crystal, regularly spaced and arranged, the difficulty of doing this is not great and is far more than counterbalanced by the simplicity gained by having to deal with symmetrical and regular bodies like cubes instead of the distorted figures of the molecule.

The solids which have the simplest constitution are crystals of the various chemical elements since in these all the atoms are of one kind. The valency of the element will have great influence upon the shape and properties of the crystals, for the crystalline shape must be such as to give the right proportion between the number of electrons and the number of atoms, and this proportion depends upon the valency of the element. Thus in a monovalent element like one of the alkali metals there is but one disposable

electron for each atom; in a divalent element there are two; in a trivalent, three, and so on.

In a crystal of a monovalent element the arrangement of atoms and electrons must be such that there is one atom for each electron. Such a proportion is ensured (*a*) if the atoms *A* are placed at the centres of cubes at each corner of which there is an electron *E*, as in Fig. 2; or (*b*) as in Fig. 3, when the atoms *A* and electrons *E* are placed alternately.

In a monovalent element the positive charge on the atom is equal to the negative charge on the electron. Thus in both the arrangements (3) and (4) we have a simple distribution of electrical charges and we can without much difficulty calculate what would be the potential energy due to the forces between them, if these are supposed to vary inversely as the square of the distance. But this is not the only source of potential energy. For by Earnshaw's theorem no system can be in stable equilibrium if the only forces between the bodies are those varying as the inverse square of the distance. There must therefore be between atoms and electrons and atoms and atoms forces in addition to those varying according to this law. I have shown in several papers that if we suppose that these additional forces between atoms and electrons vary inversely as the cube of the distance, we get simple explanations of many chemical phenomena, such, for example, as valency and Mendeleeff's Periodic Law. The result of considering the consequences of the inverse cube law when applied to the theory of solids also furnishes very strong evidence in its support. For supposing that the only forces in addition to those varying inversely as the square of the distance are those forces varying as the inverse cube, we can calculate the potential energy of the crystal. I have made this calculation in a paper published in the April number of the *Philosophical Magazine*, and find that the potential energy for each atom of a monovalent element and its associated electron is when the atoms and electrons are arranged as in Fig. 2, equal to

$$-1.825\,\frac{e^2}{d}$$

where d is the distance between two atoms and e the charge on

an electron. If M is the mass of an atom, Δ the density of the crystal will be equal to

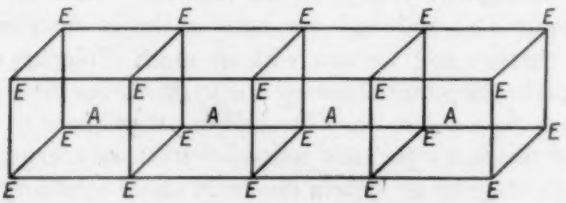
$$\Delta = \frac{M}{d^3} \text{ for } \frac{1}{d^3}$$

is the number of atoms per unit volume.
Thus,

$$\frac{1}{d^3} = \frac{\Delta}{M}$$

and as both M and Δ are known, the value of d is determined.

FIG. 2.



If the atoms and electrons are arranged as in Fig. 3, the energy per atom with electron is equal to

$$-.885 \frac{e^2}{d'}$$

where d' is the distance between an atom and an electron and is given by

$$\frac{1}{d'^3} = \frac{2\Delta}{M}.$$

Now if we compress the solid we shall alter d, and with d the energy of the crystal. From the preceding expressions we can find the energy required to produce any specified compressions, and from this we can deduce the coefficient of compressibility of the solid. In this way I find that the bulk modulus K (which is the reciprocal of the compressibility) is given by the relation

$$K = \frac{3.65}{9} e^2 \left(\frac{\Delta}{M}\right)^{\frac{1}{3}}$$

for the arrangement in Fig. 2 and by

$$K = \frac{2.2}{9} e^2 \left(\frac{\Delta}{M}\right)^{\frac{1}{3}}$$

for that in Fig. 3. As e and $\frac{\Delta}{M}$ are known for the different elements, we can find the value of K. The following tables contain

the values of K calculated by the first of these formula and also the value found by Richards in his invaluable researches on the compressibility of the elements.

	K calculated	K found by Richards
Lithium	$.14 \times 10^{12}$	$.114 \times 10^{12}$
Sodium	$.068 \times 10^{12}$	$.065 \times 10^{12}$
Potassium	$.03 \times 10^{12}$	$.032 \times 10^{12}$
Rubidium	$.022 \times 10^{12}$	$.025 \times 10^{12}$
Cæsium	$.016 \times 10^{12}$	$.016 \times 10^{12}$

Thus we see that not only the relative values of the compressibility, but also the absolute ones, are given accurately by the expression which corresponds to the arrangement represented by

FIG. 3.

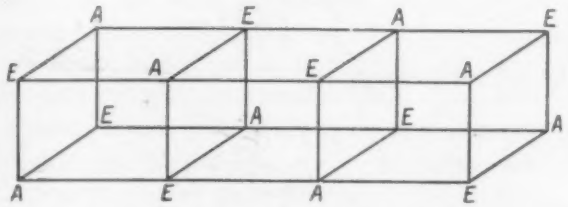


Fig. 2. The values corresponding to the arrangement in Fig. 3 are little more than half these, and are ruled out of court by Richards' experiments. We conclude then that Fig. 2 represents the arrangements of atom and electrons in the alkali metals.

A further test of theory is got by considering the elements with higher valencies. Let us take first the divalent elements where there must be two disposable electrons for each atom. This necessitates an arrangement of electrons quite different from that for the alkali metals. One arrangement which gives two electrons for each atom is to place the electrons at the corners of hexagonal prisms and the atoms at the centres of the prisms. As each corner is the meeting place of six prisms the twelve electrons will only count as two, and there will be two electrons for each atom. This would give hexagonal symmetry and would involve crystallization in the hexagonal system. As a matter of fact most divalent elements do crystallize in that system. The calculation of the energy corresponding to this distribution of electrons is more complicated than that for the alkali metals, because two lengths are required to fix the hexagonal prism; *viz.*, the height and the radius of the base. This makes the numerical calculations

somewhat lengthy, and I have not yet completed them. I have, however, calculated the energy for another distribution of electrons which would also give two electrons per atom, which would correspond to crystals with uniaxial symmetry, and for which the geometry is simpler. In this arrangement the atoms are at the centres of cubes, and the electrons at the corners of the cubes and at the middle points of *one* pair of parallel faces.

For this distribution I find that the potential energy per atom with two electrons is

$$-10.27\,\frac{e^2}{d}$$

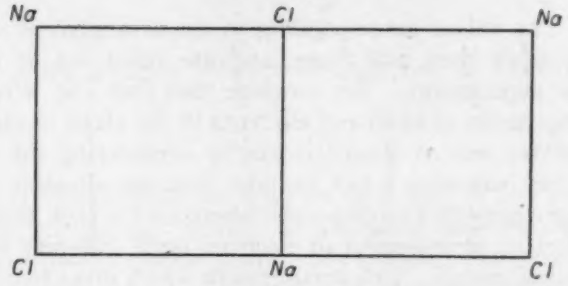
where e is the charge on an electron and d the size of the cube. If Δ is the density of the crystal and M the mass of the atom

$$\frac{1}{d} = \left(\frac{\Delta}{M}\right)^{\frac{1}{3}}$$

so that the potential energy is

$$-5.13\,e^2\left(\frac{\Delta}{M}\right)^{\frac{1}{3}}.$$

FIG. 4



It follows from this that K, the bulk modulus, is given by the equation

$$K = \frac{10.26}{9}\,e^2\left(\frac{\Delta}{M}\right)^{\frac{1}{3}}.$$

The values of K, calculated from this expression, and the values found by Professor Richards, for the divalent element, are given in the following table

	K calculated	K observed
Magnesium	$.408 \times 10^{12}$	$.378 \times 10^{12}$
Calcium	$.185 \times 10^{12}$	$.182 \times 10^{12}$
Zinc	$.72 \times 10^{12}$	$.67 \times 10^{12}$
Cadmium	$.45 \times 10^{12}$	$.53 \times 10^{12}$

Let us now consider the trivalent elements; for these there are three electrons per atom. There are several ways in which the electrons might be arranged which would correspond to different systems of crystallization. The arrangement corresponding to the cubical form is when the atoms are placed at the centres of regular dodecahedra with the electrons at the corners. Space can be packed with these dodecahedra, and when this is done each of the six four-edged corners of a dodecahedra is the meeting place of six dodecahedra, while each of the eight three-sided corners is the meeting place of four; thus the six four-edged corners count as one and the eight three-edged as two, and, therefore, the fourteen corners of the dodecahedra as three.

We can show that when dodecahedra are packed in this way the centres are arranged like a system of face-centred cubes; the electrons are at the middle points of the sides of these cubes and also at the centres of the eight smaller cubes into which a cube is divided by planes bisecting its sides at right angles.

I have calculated the potential energy per atom and their electrons for this arrangement and find that it is equal to

$$-14.4\,\frac{e^2}{4^{\frac{1}{3}}}\left(\frac{\Delta}{M}\right)^{\frac{1}{3}}$$

and the bulk modulus is

$$\frac{28.8}{9}\,\frac{e^2}{4^{\frac{1}{3}}}\left(\frac{\Delta}{M}\right)^{\frac{4}{3}}$$

where Δ is the density of the crystal and M the mass of the atom. Aluminium is a trivalent element crystallizing in the regular system, for which $\frac{\Delta}{M}$ is

$$\frac{2.65}{27}\times\frac{1}{6.4\times 10^{-24}}.$$

Substituting this value we find the bulk modulus to be $.98\times 10^{12}$, the value found by experiments is $.78\times 10^{12}$.

For quadrivalent elements there must be four electrons for each atom. The arrangement which would give this proportion and produce crystals belonging to the regular system is when the atoms are at the centres of cubes and the electrons at the corners and middle points of all the faces of the cube.

I have shown [1] that the potential energy per atom with four electrons is equal to

$$-16.67\ e^2\left(\frac{\Delta}{M}\right)^{\frac{1}{3}}$$

and that the bulk modulus is equal to

$$\frac{33.35}{9}\ e^2\left(\frac{\Delta}{M}\right)^{\frac{1}{3}}.$$

The diamond crystallizes in the regular system, for it $\Delta = 3.52$. This would make the bulk modulus for the diamond 8.1×10^{12}; this is very much higher than the value 2×10^{12} obtained by Richards. This difference suggests that the unit in the case of the diamond is a group of three or four atoms and not a single atom. We see from the preceding investigation that whatever be the valency of the element the expression for the bulk modulus contains the factor $\left(\frac{\Delta}{M}\right)^{\frac{1}{3}}$; the other factor depends only on the valency and increases as that increases.

The expressions for the potential energy of an atom with its associated electrons given above are for atoms in the body of the crystal; for atoms at the surface the potential energy will be greater. Suppose that βE is the excess of an atom at the surface over the energy E possessed by an atom in the interior. If d be the distance between the atoms, the number of atoms per unit area of surface is $\frac{1}{d^2}$, so that the excess of energy possessed by unit area of surface is $\frac{\beta E}{d^2}$, and this must equal to T the surface tension; hence since, as we have seen, E varies as $\frac{1}{d}$

$$T = \frac{\beta'}{d^3}$$

where β' is a constant proportional to β and depending upon the valency. But K, the bulk modulus $= \frac{\gamma}{d^4}$, where γ is quantity, depends on the valency, thus

$$T = \beta' \frac{k^{\frac{3}{4}}}{\gamma}.$$

For substances of similar constitutions both β' and γ will have the same values; hence for such substances T will be proportioned to $K^{\frac{3}{4}}$. This relation was dicovered by Richards.

[1] *Philosophical Magazine*, April, 1922.

Hitherto we have confined our attention to elementary substances; similar principles will also apply to compounds, though for these the calculation of the potential energy is much more complicated. The reason for this is that when the atoms are different the distribution of electrons round one kind of atom need not be the same as that round the other kind. Thus, take NaCl as an example; there are eight electrons for each molecule of the salt. If the atoms of Na and Cl are arranged alternately as in Fig. 4, one way of disposing of the electrons would be to place them at the corners of cubes whose centres are at the chlorine atoms and whose sides are parallel to the lines of the space lattice formed by the sodium and chlorine atoms. With this arrangement the crystals would belong to the regular system. The measure of its physical properties would depend upon the dimensions of the cube of electrons round the chlorine atoms. If the side of this cube is small compared with the distance between the atoms of sodium and chlorine, we can prove without difficulty that the expression for the bulk modules would be the same as given for the arrangement Fig. 3 for a monovalent element, the bulk modulus calculated on this assumption would be much less than the value found by Richards for NaCl. If we go to the other extreme and suppose that the cube round the Cl atom extends half-way to the Na atom, the electrons will be arranged as face-centred cubes and the expression for the energy and bulk modulus will be that given for a quadrivalent element. The bulk modulus calculated in this way is much greater than that found by Richards; thus for some dimensions of the cube intermediate between these values the calculated value of the bulk modulus will agree with that found by Richards. If we know the intensities of the forces varying inversely as the cube of the distance, we can calculate the dimension of the cube of electrons, the calculation is, however, somewhat lengthy, and I must leave it for another occasion. I may remark, however, that Richards' result for the halides of the alkali metals show that these are in very fair agreement with the general result that for similar bodies the bulk modulus is proportional to $\left(\frac{\Delta}{M}\right)^{\frac{1}{3}}$.

An Alcohol Problem.—At the last meeting of the Association of Official Agricultural Chemists, a discussion was held in regard to the respective advantages of the tables published by the Association and those recognized by the United States Pharmacopeia. The A.O.A.C.

tables are based on the Bureau of Standards data 20°/4°, and represent true specific gravities, whereas the U. S. P. tables are based on the Bureau of Standards tables 15.56°/15.56°, and represent apparent specific gravity of 750 millimetres and 50 per cent. air saturation. The A. O. A. C. tables are favored from a purely scientific point of view, but trade considerations in an industry so intricate in its public relations cannot be overlooked. Sixty degrees/sixty degrees F. is written into the United States Revenue law. The question of temperature is important only in the case of per cent. by volume. The A. O. A. C. rules which require specific gravity refractive index and rotation to be determined at 20° make for uniformity. An expression of opinion by those interested in the matter is desired. Such opinion should be transmitted to L. F. Kebler, Chairman, Washington, D. C.

H. L.

Chemical Studies of Swimming-pool Water.—ROY W. GOSHORN, of the Hahnemann Medical College of Philadelphia (*Hahnemannian Monthly*, 1922, lvii, 460–469), has examined the water from five swimming pools in Philadelphia; one pool was used exclusively by women, two pools exclusively by men, and two pools by both sexes. From six to fifteen samples were taken from each pool at definite intervals of time; determination was made of the concentration of chlorides, nitrogen as free ammonia, nitrogen as nitrates, nitrogen as nitrites, and nitrogen as urea in each sample. The treatment of the water and the number of people using the pool between analyses were also noted. The contamination of the water was greatest in the pool used only by women, and least in the pools used only by men; pools used by both sexes occupied an intermediate position with respect to contamination. These findings were based on the concentration of urea, nitrates, nitrites, and free ammonia in the respective groups of pools. Treatment of the water with cupric sulphate apparently had no influence upon its chloride and nitrate content.

J. S. H.

Sealing Quartz to Glass.—E. O. HULBURT, of Iowa State University (*Science*, 1922, lvi, 147), recommends the use of silver chloride for sealing quartz to glass. For example, the end of a glass tube was ground evenly, warmed to a temperature above 500° C. in a Bunsen flame and quickly dipped into powdered silver chloride. The silver chloride, which adhered to the glass tube, was melted by further heating. The tube was secured in an upright position; the plate of quartz was placed on top of it; and heat was applied until the silver chloride melted and made optical contact with the plate. Fused quartz plates fractured less frequently than plates cut from quartz crystals, hence were preferable. Glass tubing with a wall of medium thickness stood the strain best after sealing had been accomplished.

J. S. H.

BRIDGES OLD AND NEW.*

BY

RALPH MODJESKI, C.E., D.ENG.

Franklin Medalist, Member of the Institute.

FROM the beginning of history, and no doubt many centuries before, the means of transportation seem to have been considered the most important factor in the progress of civilization. In his history of the Great Highways of the Roman Empire, Bergier says:

"The Rulers of the various countries took great care to maintain the highways in such condition that the people could traverse them with security and convenience; the Kings of Sparta were especially charged to see to the good condition of the roads; Augustus, elected the curator of the great highways in the vicinity of Rome, engaged as helpers persons of pretorian dignity; in France, the King, in the early times, had reserved for himself the superintendence of the great highways; he delegated the carrying out of this supervision to his 'Grand Voyer'; Henry IV appointed as 'Grand Voyer' his Prime Minister Sully, that is, the man whom he esteemed most."

The existing records of ancient bridges, meagre as they are, seem to indicate that men were building bridges at least sixty centuries ago.

We do not know exactly when one type of bridge followed another; but it is certain that all our modern types, such as girder, arch, suspension, and even cantilever, were used in primitive shape in those very ancient times. We have still existing examples of the beam or girder bridge; monuments proving age-old knowledge of a rudimentary arch; we have records of the early use of the suspension type; and records of the cantilever combined with the girder type connecting-span almost challenging our credulity.

The first bridge built by man no doubt was of the kind easiest to build—possibly a tree thrown across a stream or ravine. Thus

* Presented at the Stated Meeting of the Institute held Wednesday, May 17, 1922.

unwittingly, the man invented the girder. But as early as 4000 B.C., notable progress must have been achieved in the art of bridge-building, for, according to Herodotus, Menes, one of the first Kings of Egypt, then had a bridge constructed over a branch

FIG. 1.

Slab bridge at Chapoo, China.

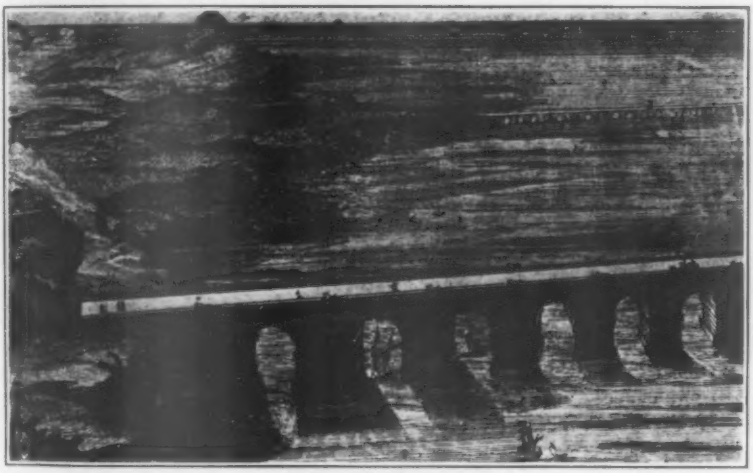
of the Nile and though we have no details of this early structure it must have consisted of at least several girders or even arches.

We have mention in history of Lake Villages in the Bronze Age, or about 1400 to 1200 B.C. They consisted of many bridges built of wood leading to a central group of dwellings. There are remains of a Lake Village in Glastonburg in the British Isles.

LINTEL AND SLAB BRIDGES.

Among the oldest monuments we have of bridge construction are the so-called lintel and slab bridges. The former consisted of oblong stones placed vertically in the stream and spanned by long, flat, narrow stones or lintels. Sometimes lintels have been placed on piers built of smaller stones. There are some examples of these ancient bridges in the Valley of Wycoller in Lancashire, England, dating back to the Bronze Age. The so-called slab bridges differed from the lintel bridges in that large slabs of stone

FIG. 2.



Bridge at Fo-Cheu, China.

were used instead of narrow ones. Some examples still exist in the Dartmoor region, England. But it is China, probably, who has built more slab bridges than all other countries combined. There, as in other countries, a single-span bridge—arch or beam—was the first form constructed. Such is the type of the bridge at Chapoo which is very ancient though information even as to its approximate age has not been found. It is a bridge for pedestrians only, built of stone slab beams resting on stone abutments; most beautifully proportioned as a whole and in all its parts (Fig. 1). There are many similar single-span bridges in China of more or less ancient origin, all of them showing the extraordinary ability and workmanship of their builders.

CHINESE ARCH BRIDGES.

Later, with the advance of civilization, bridges of greater length—of more spans—made their appearance. Emiland Gauthey speaks of a bridge, said to be still in existence, at Loyang, in the province of Fo-Kien, which has three hundred spans; it took eighteen years to build it, and five thousand men were employed. It is probably a slab bridge. The slabs are said to be of huge dimensions: about 9 feet by 15 feet by 100 feet. Gauthey further expresses a doubt as to the correctness of these dimensions and according to Pingeron they are only about 4½ feet

FIG. 3.

Bridge at Srinegar, India.

by 4½ feet by 45 feet. Even then, Gauthey says: "It is a wonderful achievement—more than four and a half times longer than the Pont Saint Esprit." Taking the dimensions given by Pingeron, the bridge is about 14,500 feet long. It is ornamented by large marble lions, a decoration which has often been used in the old Chinese bridges. It is again Gauthey who describes a bridge of 24,000 feet in length in the province of Fo-Cheu, over the river Min. It is said to have a hundred arches, all semicircular, of an average opening of 128 feet, and a width of 60 feet. The piers, therefore, are very broad, and the height is 120 feet. This bridge also is ornamented with huge lions in black marble cut out of blocks twenty-two feet long. It was said of this bridge that vessels could pass under the arches with all sails set (Fig. 2).

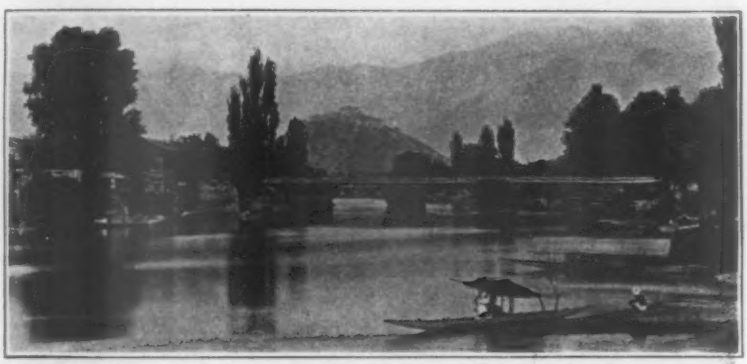
PRIMITIVE CANTILEVER BRIDGES.

However it may stand between the wooden and the stone span as to priority in history, there came a time when the two materials were combined in the construction of bridges.

The Lake Village bridges were apparently all of wood while the lintel and slab bridges were of stone; both these types, as said before, dating back to the Bronze Age.

But Violet le Due found in Savoy (France) a primeval bridge built of logs laid criss-cross, each layer of logs projecting beyond

FIG. 4.



Bridge at Srinegar, India.

the one below and the crib thus formed filled with rock. These cribs then had the shape of brackets or cantilever arms projecting over the stream. The gap between them was bridged with timber. Here we have a prototype of the cantilever bridge. Criss-cross bridges of several spans may still be found in use in Kashmir, India, and in other eastern countries.

The bridges at Srinegar, India, built of deodar logs, are typical examples of this kind of construction; they have several piers, each corbeling towards its neighbors, the remaining spaces being bridged over by long beams (Figs. 3 and 4).

One of these bridges has houses or shops built closely side by side over the whole length of it. This idea has been repeated often in European bridges; as in the well-known old London Bridge, the Ponte Vecchio in Florence, and in certain old Swiss bridges. The merchants evidently selected a location where passing their shops was unavoidable.

A still nearer approach to the true cantilever is seen in the primitive form in the bridge near Darjeeling, in the Himalaya Mountains, N. W. India (Fig. 5).

LEGENDARY BRIDGES.

Herodotus mentions that a magnificent bridge was built over the Euphrates at Babylon. This bridge is said to have had stone piers connected by planking which was removed at night. As

FIG. 5.

Bridge near Darjeeling, India.

building foundations under water was not known, the river was diverted during the construction of the piers. Diodorus ascribes the bridge to Semiramis, which would place it nearly 800 B.C. There is an historical mention of large pontoon bridges built by Darius on the Danube about 500 B.C. and somewhat later one by Xerxes on the Hellespont, but unfortunately no details of the construction of these various structures have reached us.

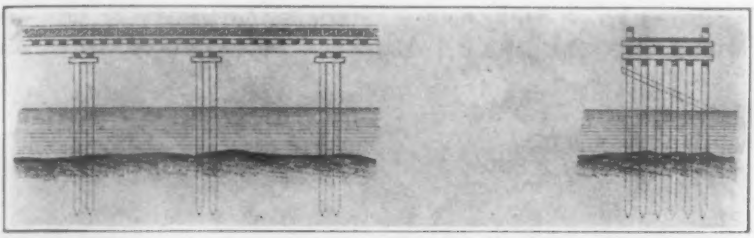
FIRST ROMAN BRIDGES.

To the Romans is due the greatest progress in bridge-building. They did not hesitate to cross the broadest streams in their march to conquest and did so by means of various types of structures—

wooden trestles, wooden arches on stone piers, or with purely stone arches.

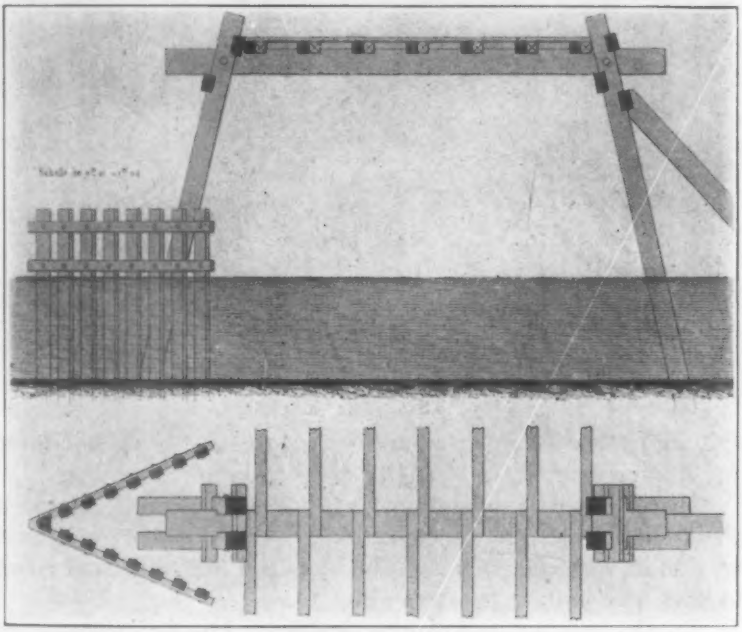
The Roman aqueducts, built about 600 B.C., consist of

FIG. 6.



Pons Sublicius.

FIG. 7.



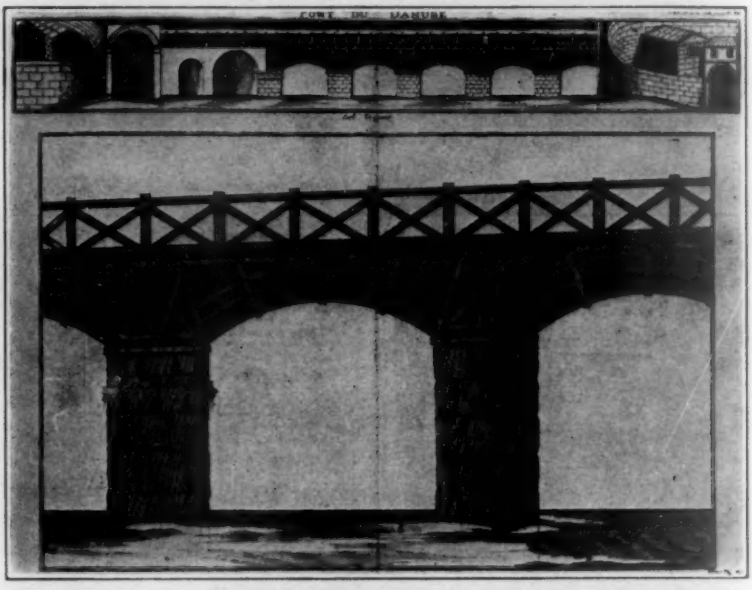
Bridge over the Rhine, built by Caesar.

masonry arches, but the opening of the arches never exceeded 20 feet.

The first Roman bridge of which we know was built of timber

in 620 B.C., at the foot of the Aventino Mountain. It was called Pons Sublicius. There is some controversy as to its exact location on the Tiber. It was built entirely of wood, not unlike our modern trestles (Fig. 6). According to Denis of Halicarnassus, this bridge was built at the expense and by the efforts of the first religious heads, whence their name "Pontifices." It was destroyed in 507 B.C., while Horatius Cocles was defending its pas-

FIG. 8.



Trajan's Bridge over the Danube.

age. Pliny says that in rebuilding it care was taken not to use any iron or nails, to facilitate its destruction in future wars.

History speaks of a timber bridge built over the Rhine by Cæsar in 55 B.C. It was temporary and simple, but said to be very solid. It was from 2000 to 2300 feet in length, and is said to have been built in ten days (Fig. 7).

Trajan was a great bridge builder. His bridge over the Danube just below the Iron Gate was in his time a gigantic undertaking. It was built probably about 104 A.D. (Fig. 8). Its engineer was Apollodorus of Damascus, who also built the Trajan Column in Rome, on which there is a bas-relief of the bridge

apparently distorted by the sculptor. The ancient historian, Dion Cassius, states that the bridge had twenty piers of hewn stone, 150 feet high and 60 feet wide, with openings between them of

FIG. 9.

Natural bridge at Han-tseuen, China.

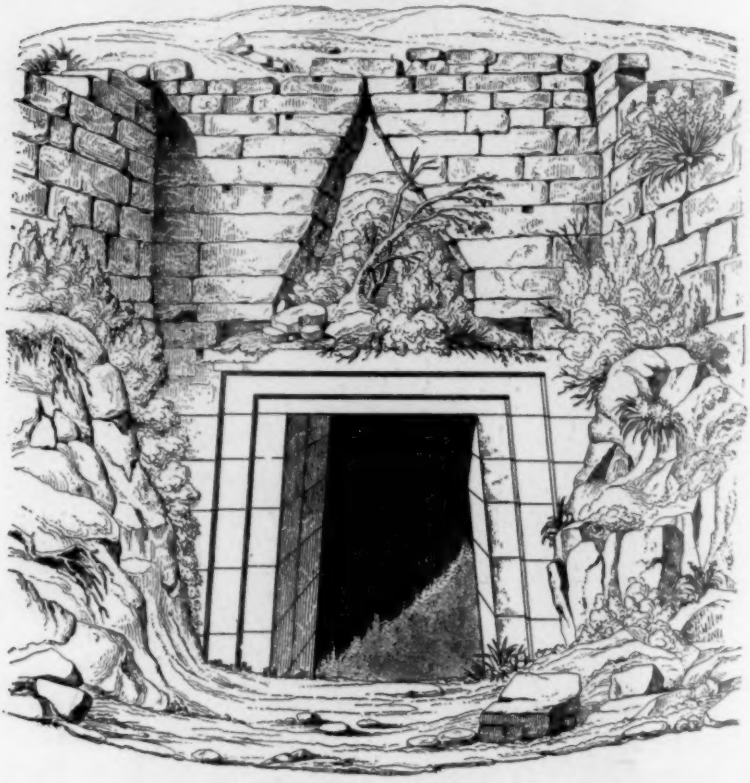
170 feet. The bas-relief gives clear information that the stone piers were connected by wooden arches. There are still thirteen piers visible out of the twenty. The length of this remarkable structure is said to have been 3900 feet (Murray's Handbook),

although other sources give this length as nearer 3000 feet. It is believed that the foundations for the piers were obtained by sinking caissons.

FIRST STONE ARCHES.

The true stone arch came to be used only after other forms of construction resembling the arch had been tried. In fact, there

FIG. 10.



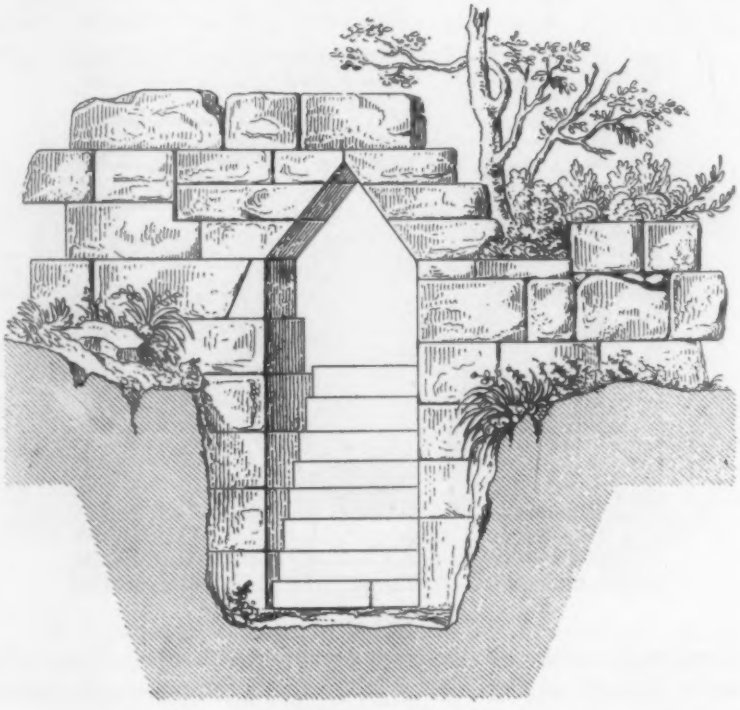
Agamemnon's Grave at Mycenæ.

seems to have been a definite process of evolution and its different stages are quite marked. No doubt the first idea of an arch came to man from some natural rock formations of which there are many throughout the world. One of the most remarkable instances, and where this natural bridge is used as a crossing, is at Han-tseuen, in the Province of Kiang-nan, China (Fig. 9).

But, being monoliths, these natural arches gave no indication of how to imitate them with smaller stones, so that the arrangement of joints became the subject of experiment through many centuries.

The Egyptians and the Greeks built arches in very ancient monuments, but they were not true arches and had only very

FIG. 11.



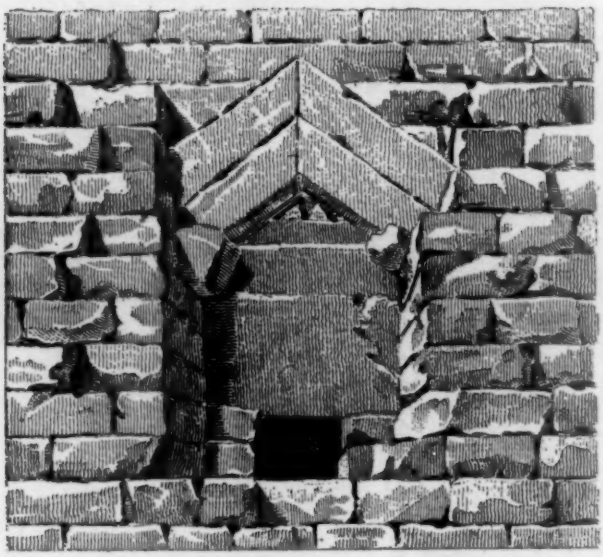
Entrance to theatre at Messina.

small openings. In Greece, especially, the first arches were built of stones laid in horizontal courses, each course projecting beyond the one below. This was first done cautiously, so that the top courses did not meet as in the later constructions but the remaining space was bridged by a lintel. An example of this endeavor to approach an arch is seen in the entrance to the commonly called Agamemnon's grave at Mycenæ (Fig. 10). The lintel still exists but the horizontal courses supporting it approach each other as they rise. The upper triangular opening shown in the cut

must have been filled by some ornamental slab which was subsequently removed. It is even possible that this was done to relieve the weight on the lintel. In the entrance to the theatre at Messina, Greece, the lintel is omitted and the approach to the arch becomes closer (Fig. 11).

But the real prototype of the true arch, where the stability depends entirely on abutment resistance to horizontal thrust, is

FIG. 12.



Entrance to the great pyramid at Memphis.

found in the entrance to the great pyramid at Memphis (Fig. 12); also in the roof of a granite grotto of cyclopean masonry, situated on the Island of Delos near the top of the Acropolis (Fig. 13).

ROMAN STONE ARCH BRIDGES AND AQUEDUCTS.

Gauthey says that Pons Salaro over the Treverone in Rome was built 600 years B.C. It is not known if it was built of stone at that time or merely of wood and replaced by stone arches later. It appears to have been a stone arch bridge by the year 361 B.C. In any event, it is probably the earliest Roman stone arch bridge. It consisted of five arches of openings varying from 22 to 69 feet. Pons Palatinus, built in 179 B.C., is now known as Ponte Rotto. One arch is still in existence.

The Romans built many stone arch bridges during the beginning of the Christian era, many of which have been partly or wholly preserved, and some of which are even still in use. The Rimini Bridge (Fig. 14), built under Augustus, is perfectly preserved. The Pons Aelius, now Saint Ange, built about 130 A.D. by Emperor Hadrian, has been repaired and ornamented with statues, but is entirely preserved (Fig. 15).

Only one arch of the bridge at Narni, Italy, built by Augustus Cæsar, remains standing, where originally there were four, of white marble, elaborately designed (Fig. 16).

FIG. 13.

Roof of grotto at Delos.

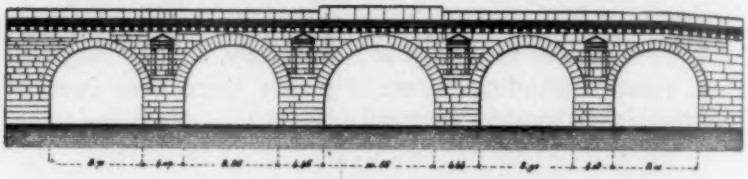
The aqueduct of Gard in France, built by Agrippa at the beginning of the Christian era to bring water to the city of Nimes from a distance of about 24 miles, was built entirely of cut stone, 158 feet above the surface of the water. No cement or mortar was used except in the uppermost arches and as a lining in the water-carrying trough. This bridge of Gard (aside from that of Metz) is the only one which remains in France of those constructed before the twelfth century, all others having been destroyed by the invading Barbaric hordes of that period. Even this structure did not escape unharmed, both its ends having been destroyed (Fig. 17).

Of the Roman bridges still preserved in Spain, we should mention the Alcantara and the St. Martin bridges. Both of these

are due to Trajan and both are very bold and remarkable structures (Figs. 18 and 19).

The gigantic aqueduct of Metz, of which ruins still remain, is another example of Roman enterprise, energy and ability in build-

FIG. 14.



Ponte Rimini, Italy.

ing great structures. This aqueduct formed a part of a very elaborate water supply system. The water of the streams was

FIG. 15.

Pons Aelius, now Saint Ange, Italy.

gathered into reservoirs from which it flowed through stone-lined tunnels, "so spacious that a man could walk through them with

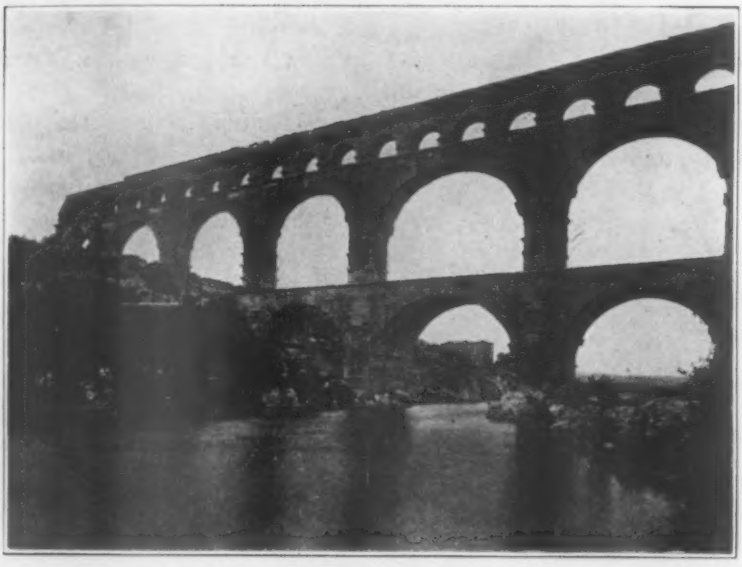
FIG. 16.

Bridge at Narni, Italy.

very little stooping," and crossed the Moselle on this viaduct. From there the water flowed through similar tunnels into the baths and into the Naumachia (Fig. 20).

Colmenares in his history of Segovia says, that the Roman

FIG. 17.



The aqueduct of Gard, France.

FIG. 18.

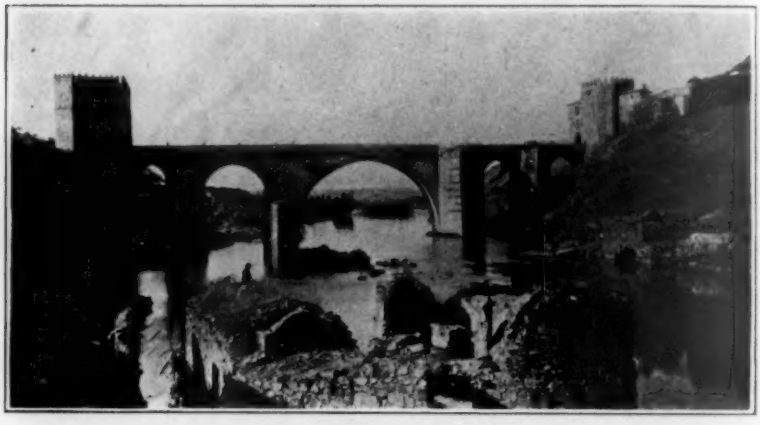
Alcantara Bridge, Spain.

aqueduct at Segovia may be cited as one of the most marvellous works left us by antiquity. Montfaucon wrote in 1722 that one hundred fifty-nine arches were still standing, all of large stones without cement. The total height was 102 feet with a double row of arches, one over the other.

Another Roman stone aqueduct is situated in Tarragone, Spain, and is very well preserved (Fig. 21).

The Romans used also brick and concrete in the construction of their aqueducts. Several ruins of this method of construction

FIG. 19.



St. Martin Bridge, Spain.

still may be seen in Italy. The one named after Nero was built of brick and was of very fine workmanship. The Alexandrine viaduct was built of brick over concrete.[1]

MEDIÆVAL BRIDGES.

The Middle Ages have left us a number of bridges in various states of preservation. They are almost entirely of stone construction—arches and piers. And almost all the bridges of the twelfth and thirteenth centuries were very narrow with very steep approach grades. Often the entire absence of parapets made it very dangerous to cross them at night. There is a feeling of difference between the points of view of the builders of the Roman times and of the Middle Ages, in spite of a common quality of

[1] W. Shaw Sparrow: "Book of Bridges."

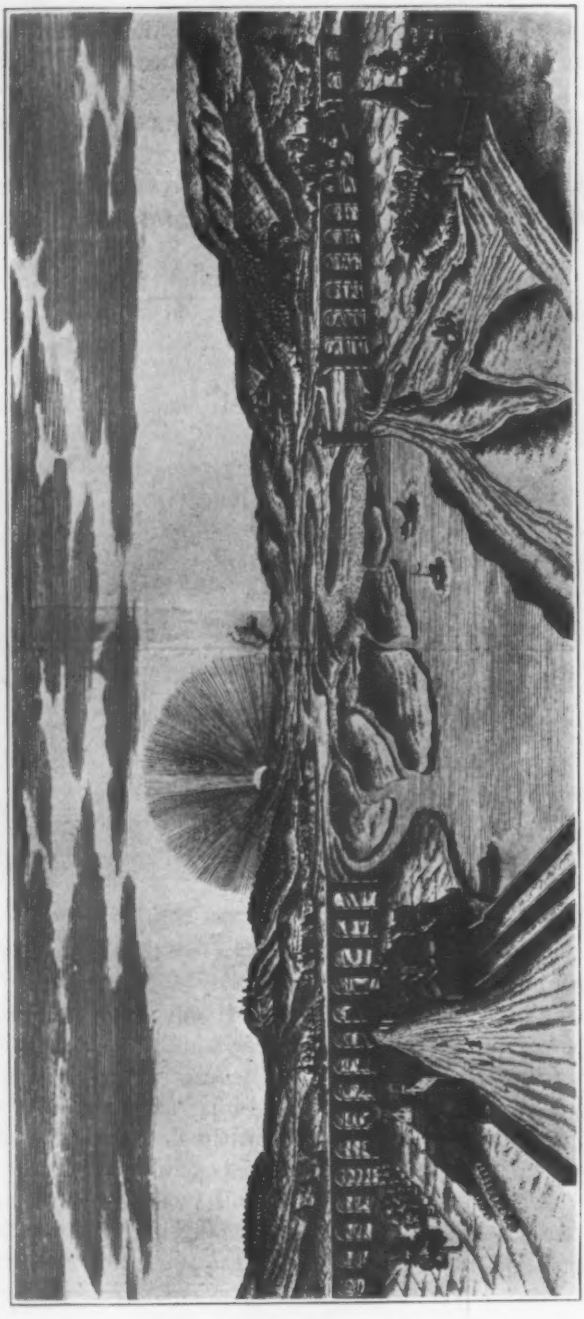


FIG. 20.

Roman aqueduct at Metz.

simplicity. The old Roman bridges seem to have been built with every line, mass and form shaped directly to meet the requirements of utility; with the result that no line or form could be questioned by the eye. But in the mediæval bridges good proportions often are hurt by a conforming to mathematical orderliness; or dignity and simplicity seem more a superficial expression of taste on the part of the monastic orders that built them.

FIG. 21.

Roman aqueduct at Tarragone, Spain.

One of the most remarkable works of those times was the Pont d'Avignon in France, built in 1178 by St. Benezet. There were twenty-one arches though to-day only four remain. The total length of the bridge was 2000 feet and the principal arches had an opening of 108 feet. St. Benezet gave his arches the form approaching an ellipse with its long axis placed vertically. This was quite a bold departure from the arches of the Romans who seemed to have used circular curves exclusively.

Over the Rhone we have the Saint Esprit Bridge, which was begun in 1265. It is said to be one of the longest stone bridges in the world and was very solidly built and strong. Its building

lasted forty-five years, being finished in 1309. It was at first planned only for pedestrians and cattle, but at the beginning of the last century it was placed in service for vehicles (Fig. 22).

The Pont de la Guillotiere, also in France, is in use at present. It has been widened lately by the addition of steel arches on both sides of the bridge, resting on the old piers.

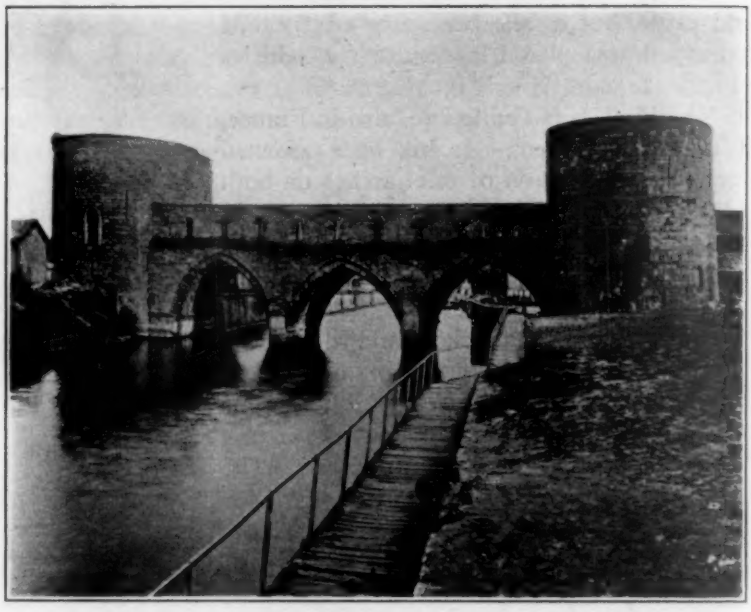
Bridges are and have been at all times the most vulnerable part of a nation's transportation system. In case of war they are the first points to be attacked and destroyed. This was plainly recognized in the Middle Ages, for most of the bridges of that time were fortified. Some conspicuous examples of such structures have been preserved. The Pont des Trous in Tournai, Belgium, for example, is protected at each end by a large tower and the parapets are high like fortress walls and provided with nine arrow-slits. Recently this bridge was again the scene of bitter struggle, when the Prussians forced a passage there (Fig. 23).

At Valentré, France, we have another example of the fortified bridge. It was built in the thirteenth century and in design has much of the grace and simplicity of the older bridges. Each of the three towers forms a vaulted passage, which could be closed by barricades when necessary. This bridge was built of small-sized stones cemented together with a mortar which has become very hard (Fig. 24).

The bridge at Orthez in the French Pyrenees, built in the twelfth century, has only one tall tower. The weight of this tower has been utilized, with Roman directness, to resist the horizontal thrust of the larger arch, being placed over the pier between the two small arches and the large one. History

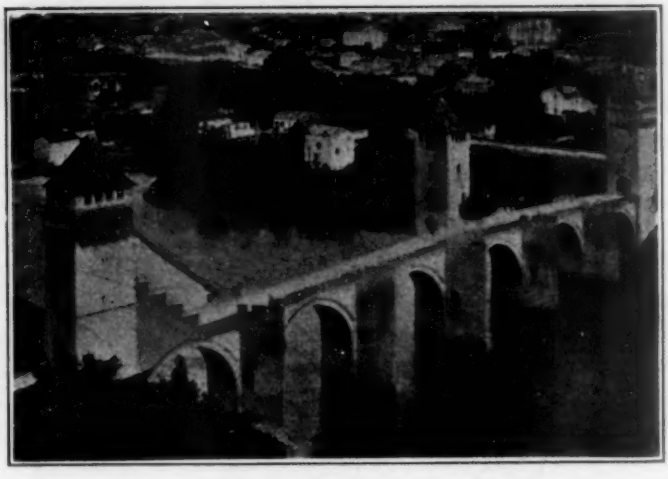
FIG. 22. Pont du Saint Esprit.

FIG. 23.



Pont des Trous at Tournai.

FIG. 24.



Port Valentré, France.

connects it with the battle of February, 1814, when Wellington defeated the French near Toulouse (Fig. 25).[2]

The bridge called Castelvecchio, at Verona, is a strange example of the fortified bridges, its distinctive battlements forming the parapets giving it an outline of unique picturesqueness. It was built in 1356. The base of the piers is built of white and red marble for about 12 feet above the ordinary water level. The

FIG. 25.

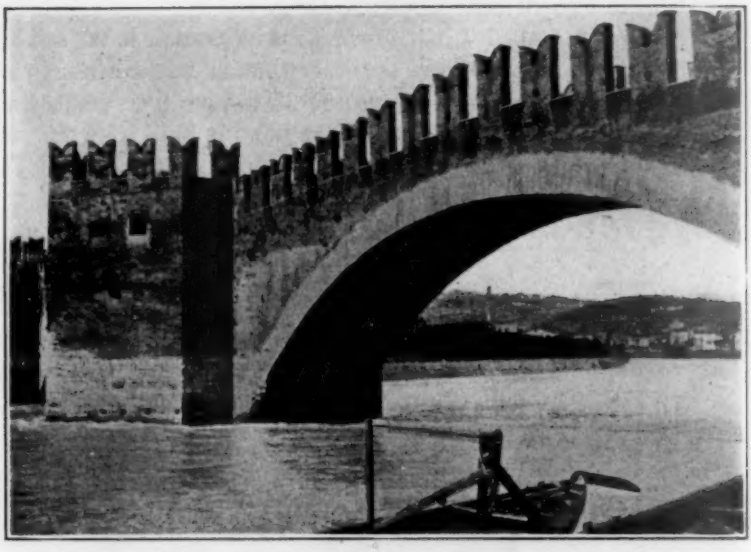
Pont d'Orthez, France.

arch wings are of limestone and the rest of brick. It is said that some of the marble was taken from Roman ruins (Fig. 26).

One of the most interesting bridges, due partly to the Romans and partly to the Middle Ages, is the Devil's Bridge at Martorell, Spain. It would seem that the bases of the piers, the abutments and the triumphal arch (not shown on cut), which are of large cut-stone masonry, are of Roman origin, while the arches and spandril walls, which are of small stones, date from the Middle Ages. Some of its arches have a curious Gothic form

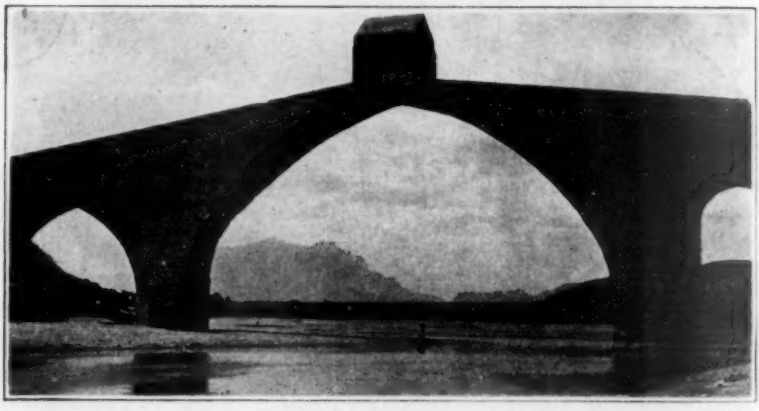
[2] Figs. 24, 25 and 26 have been taken from Paul Sejourné's "Grandes Voutes."

FIG. 25.



Castelvecchio Bridge, Verona.

FIG. 27.

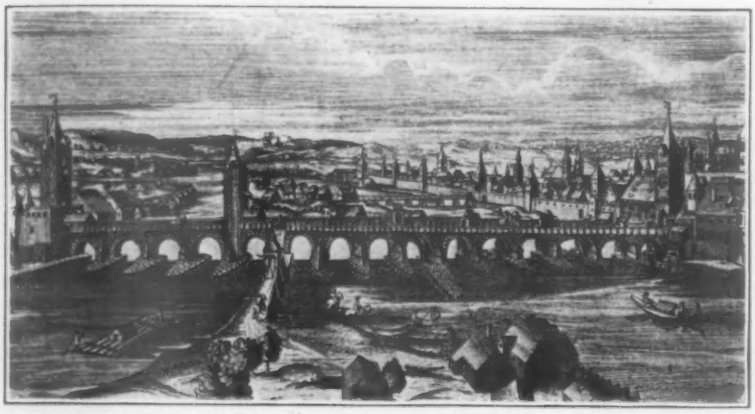


Devil's Bridge at Martorell.

and the top of the large arch, which has an opening of 145 feet, is held down by a chappel. The large arch has two superposed arch-rings and a third one near the upper part of the arch, which diverges from the other two at a point about one-third down from

the summit and loses itself in the spandril walls. This method of superposed arch-rings without any interlocking between them is very characteristic of arches of the Middle Ages (Fig. 27).

FIG. 28.

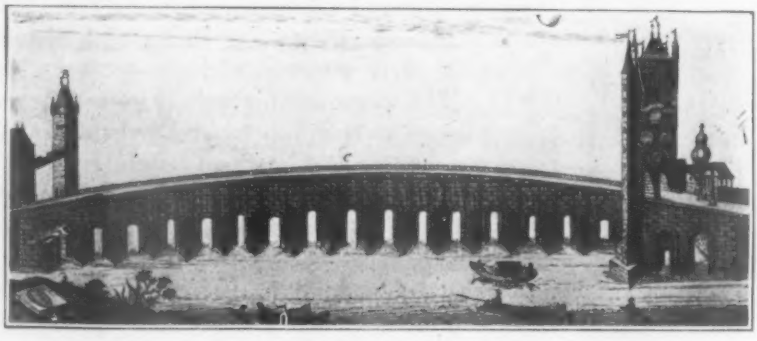


Regensburg Bridge, Austria.

LARGE STONE-ARCH BRIDGES OF THE XVIITH AND XVIIITH CENTURY.

Of the later bridges, one built in Regensburg, Austria, shows how little confidence the engineers had in the foundations, for

FIG. 29.



Bridge at Prag.

they protected the piers by large cribs filled with stone, which cut off the greater portion of the waterway (Fig. 28).

The bridge at Prag was begun in 1638 but not finished until

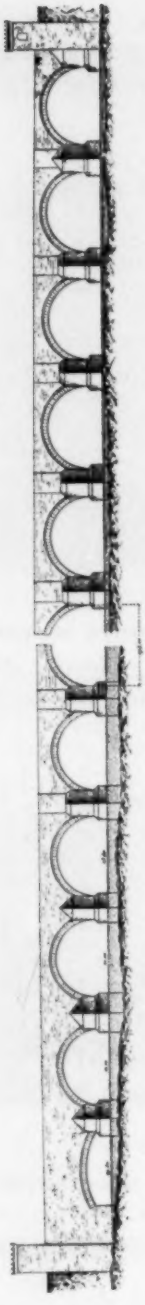


FIG. 30. Bridge at Prag.

the beginning of the eighteenth century. At the time it was built it was one of the four largest bridges in existence. Also it was considered the widest one; its width between parapets being over 35 feet (Figs. 29 and 30).[3]

LONG-SPAN WOODEN BRIDGES OF THE XVIIITH CENTURY.

About one hundred years after the Prag bridge was built wood made a sudden reappearance as bridge material, this time for spans of considerable length. Two village carpenters, Jean and Ulrich Grubenmann, born at Teufen, Switzerland, began to build long-span bridges of timber, employing a most ingenious system of their own invention. In 1755 Ulrich began his bridge over the Rhine in Schaffhausen and completed it three years later. It consisted of two spans of a total length of 364 feet with a width of roadway of 18 feet. It was supported on masonry piers (Fig. 31). The bridge was covered with a roof—a practice generally and properly followed in most timber highway bridges of those times. At the same time Jean built a similar bridge at Reichenau with a span of 240 feet and a little later both brothers built the Wittingen Bridge near Baden with a single span of three hundred and ninety feet (Fig. 32). The length of this span is given by some authorities as only 366 feet. Even then it was an astounding achievement considering that calculations of stresses or even the strength of timber in compression were entirely unknown. Since the Grubenmann brothers, wooden bridge-building has made no progress in Europe. It was further developed in the United States but, as will be seen later, on entirely different lines.

[3] Fig. 30 is added to correct the impression which Fig. 29 may give that the bridge was built on a vertical curve. While the picture is not as elaborate, it is probably more accurate.

SUSPENSION BRIDGES.

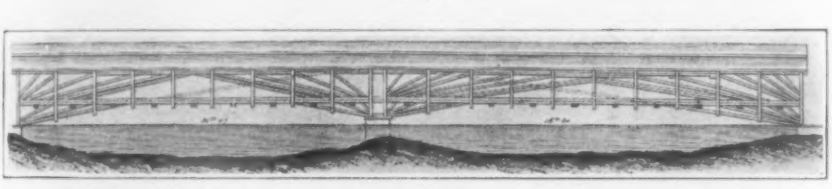
The suspension bridge is probably as old as other types and may have been originally inspired by vines hanging over a stream. There is a suspension foot-bridge in Guatemala near Lake Izabal which vividly suggests this origin (Fig. 33).

A cane bridge in Sikkim Valley, India, is another example of this simple and primitive construction (Fig. 34).

The first suspension bridge cables were either of wires or ropes and the floor followed closely the curve of suspension.

Leopold speaks of a very old suspension bridge in China built from rock to rock, consisting of twenty very heavy iron chains covered with planks. Here the rocks acted both as towers and as anchorages (Fig. 35).

FIG. 31.



Bridge at Schaffhausen, Switzerland.

Not until the end of the eighteenth century was the idea carried out of suspending a horizontal roadway from the cables, although a very rare and ancient work, entitled "Machinæ novæ Fausti Verantii Siceni," illustrates the principle of the Faustus Verantius Bridge, calling it "portable and convenient for the armies" (Fig. 36).

In England in 1819 Sir Samuel Brown built a suspension bridge over the Tweed which had a span of 449 feet. In 1826 Telford completed his famous suspension bridge over the Menai Straits. It is still in very good condition. The span is about 580 feet and is hung from iron chain cables (Fig. 37).

The Americans seem to have preceded the Englishmen in building suspension bridges with chain cables of long spans. In 1808 there were over forty suspension bridges in the United States constructed under the Finley system. Engineer James Finley employed cables made of long chain links, and later, of iron bars.

The first wire-cable suspension bridge seems to have been one built over the Schuylkill River in 1815. It was a foot-bridge only,

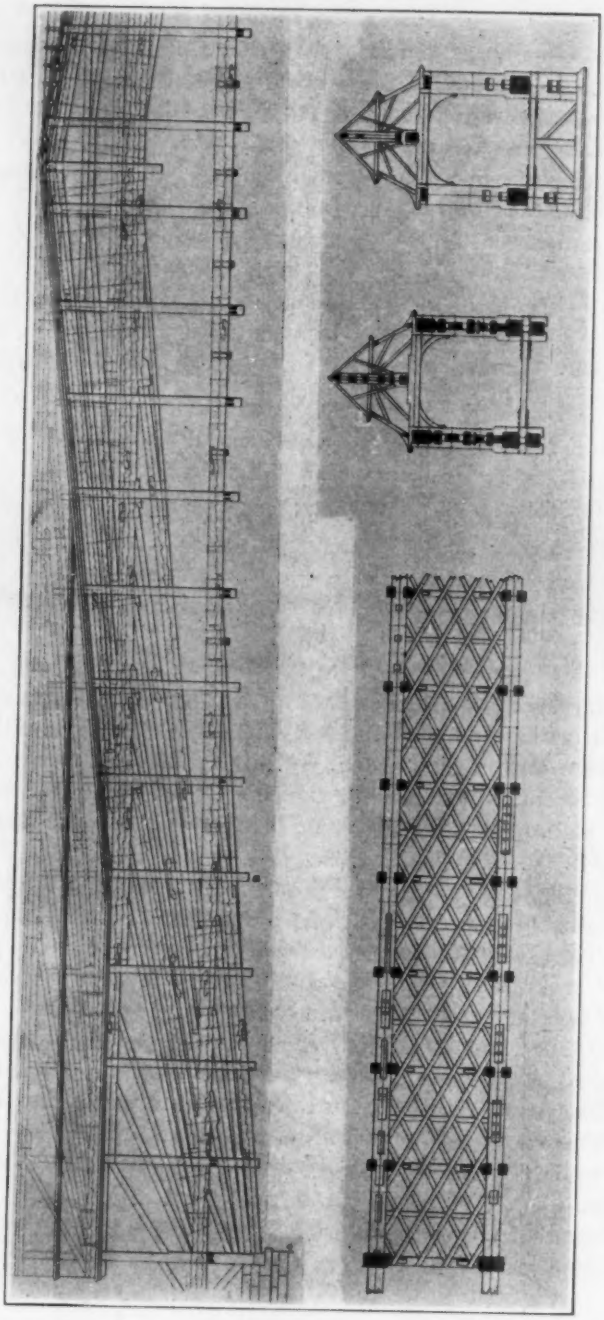


FIG. 32.

Bridge at Wittingen.

of 400 feet span. Since then the building of suspension bridges has made great progress and now they are recognized as the best-known form of construction for very long spans. Everyone is familiar with the New York bridges which are the longest suspension spans in the world.

DEVELOPMENT OF METAL BRIDGES.

Iron was known in China, India, and Egypt for a long time. Steel also was known about 500 B.C. but was not made in Europe

FIG. 33.

Foot-bridge near Lake Izabal, Guatemala.

until the thirteenth century. Cast iron, strange to say, came still later, but was the first to be used in metal bridges. Abraham Darby is credited with having built the first cast-iron bridge. In 1779 he completed the well-known bridge at Coobrookdale, England. It is an arch of 50 feet rise and 100 feet opening. This was followed by other cast-iron bridges in England as well as in France.

In 1844 wrought iron was first used in bridge work in the form of girders. In 1850 Stephenson built the tubular bridge over Menai Straits. This was followed rapidly by other tubular

bridges in England and Canada, some of their designs being more original than efficient. Most of them have stood well, however, probably because of large excess of material used. One of the most remarkable examples is the Saltash Bridge built by Brunel in 1858. It is a large, single, curved tube placed above the roadway and connected with curved bottom chords. The tube was made of elliptical section and its width was determined by the

FIG. 34.

Foot-bridge in Sikkim Valley, India.

width of the roadway below. The two main spans are each 456 feet long. The bridge is said to be still in use (Fig. 38).

Experiments with tubular designs were soon followed by lattice girders and steel arches. In France lattice girders continuous over three or more supports were at first quite popular. Later, simple spans with curved top chord seemed to find more favor. A very neat design is that of a bridge near Dinan, France (Fig. 39).

Probably the most decorative designs in steel were obtained by using arches. A beautiful example of such construction is seen

in the Eads Bridge at St. Louis; another good example is the bridge at Coblenz, Germany (Fig. 40).

THE FORTH BRIDGE AND THE QUEBEC BRIDGE.

Then came the gigantic work of the Forth Bridge with 1790 feet spans (Fig. 41) and, lately, that of the Quebec Bridge with an 1800-feet span.

These two bridges have the longest spans in existence and are both of the cantilever system. Yet the methods followed in their

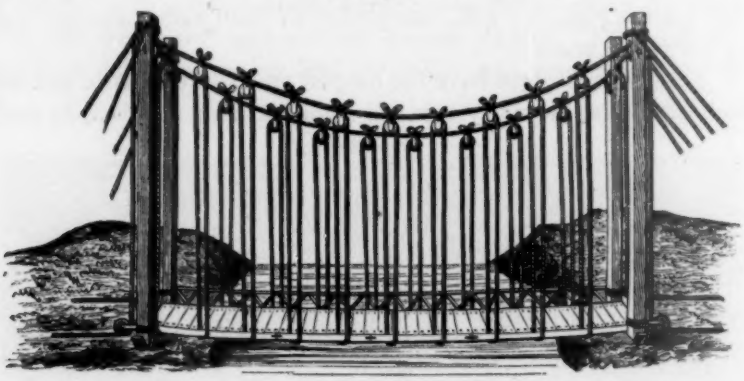
FIG. 35.

Suspension bridge in China.

design and construction were radically different. The Forth Bridge has all its compression members of tubular construction and all connections between the different truss members are rigidly riveted. In the Quebec Bridge the compression members are built of parallel webs latticed while the main tension members are of eye-bars; pin connections have been used throughout the trusses instead of riveted joints. In the Forth Bridge plates were shipped from the mills to the bridge site where they were bent, punched or drilled and fitted into place plate by plate, and the number of workmen in the field is said to have reached, at a certain time, six thousand. The Quebec Bridge members were manufactured in shops specially constructed for this work, and shipped in large

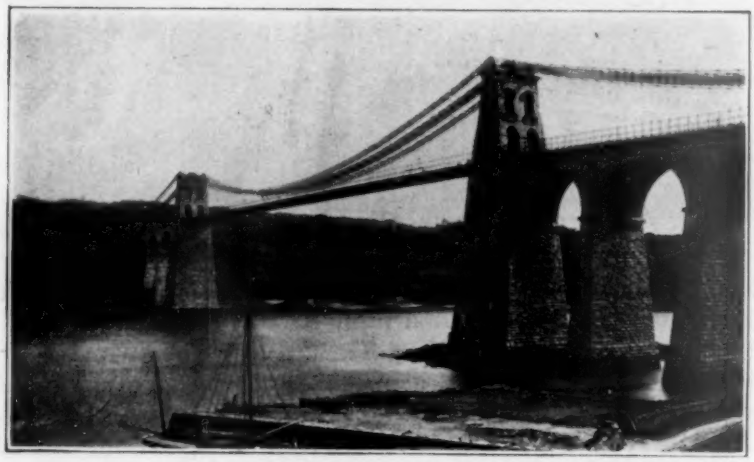
units to the bridge site, where driving of pins and some riveting was all that was necessary to assemble the structure. It is true that the Quebec work required much heavier lifting and handling-

FIG. 36.



Pons Faustus Verantius.

FIG. 37.



Bridge over the Menai Straits.

machinery than the single plates of the Forth Bridge, but, on the other hand, the required amount of labor in the field was greatly reduced and a comparatively small force was used. In each instance, however, the particular method was justified. The Forth

FIG. 38.

Saltash Bridge, Plymouth.

FIG. 39.

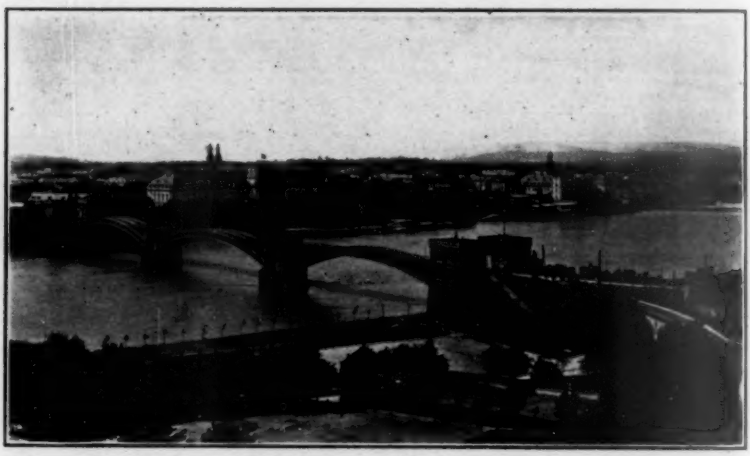
Bridge near Dinan, France.

Bridge method by the cheapness of labor at the time and place of its building and the Quebec Bridge method by the improved erection machinery and greatly increased cost of labor.

REINFORCED CONCRETE.

Within recent years a new heterogeneous material has come into wide use in engineering, not only for bridges but for other structures as well. Mehan and Monnier first demonstrated the value of steel reinforcement of concrete. There are now many examples of reinforced concrete bridges. As is usually the case with new things in construction, many failures have occurred; but the lessons from such failures together with theory, laboratory tests

FIG. 40.



Arch bridge at Coblenz.

and the successful structures, go to make up the knowledge of correct design. This knowledge is not yet complete; one may say that it is in its infancy although it is growing rapidly; with a tendency to more caution and better judgment and less struggle for economy which is often only apparent and always dangerous.

BRIDGE CONSTRUCTION IN THE UNITED STATES.

We have seen that wood was used in Europe as bridge material in the very beginning of civilization. In the United States, wood was again largely resorted to at first, in the early rapid development of its means of transportation. This, however, was due entirely to economic considerations, both from the point of expense and of celerity. During the very rapid development of the railroads in this country, it became necessary at first to use the cheapest and quickest means of bridging. The wooden truss

was therefore used extensively during the first growth of the railroads and highways, to be replaced later by a more substantial and permanent form of construction. Among the early wooden structures, we are told of a quite remarkable one built by Louis Wernwag in 1813. It was a bridge over the Schuylkill River which had a span of 340 feet, supposedly the longest wooden bridge ever built in the United States. After several systems of wooden construction had been tried, with more or less success, the wooden Howe truss, invented by William Howe, made its appearance. The first structure of this type was built in 1840. It was a highway bridge with a 75-foot span. Due to its simplicity,

FIG. 41.

Firth of Forth, Scotland.

facility and quickness of construction, the system soon became generally used by nearly all the railroads in this country. Even to this date those wooden truss bridges may be seen on some less prosperous railroad lines.

With the expanding iron industries, wrought and cast iron soon replaced wood, but the necessity still existed for quick and easy erection of bridges in the field, with the least amount of labor and machinery, and therefore engineers were exerting their ingenuity to invent systems of trussing which would meet those requirements. And so there came a period of the various systems, such as Bollman, Fink, Post, Linville, Pettit, Warren, Pratt, etc., most of which are now obsolete.

These systems were all based on connecting the truss members by pins, which greatly reduced the work of assembling in the field.

The pin-connected system is characteristic of American bridges and marked a great advance in this branch of engineering. It is now being replaced in smaller spans by riveted connections but in long truss spans, it is still the most practical method of construction.

In these early times of bridge construction in this country, or prior to 1880, the metals used were wrought and cast iron exclusively; the only exception being the Eads Bridge in St. Louis, in which Captain Eads used chrome steel for the first time; and excepting steel used in the wires of suspension bridges, some of which were built prior to that year. In the meantime, iron mills began to manufacture steel, first Bessemer, then open hearth, and gradually cast iron was replaced by wrought iron which, in turn, was replaced by Bessemer steel and finally by the open-hearth steel which is now generally used.

In recent years alloys of steel have been used more and more —nickel steel, chrome-nickel steel and silicon steel. These materials, because of their increased strength, prove economical for long spans. For the same reason, they also make it possible to build longer spans than could practically be done with ordinary steel. We have not yet reached the full possibilities of alloys as bridge materials, and we may expect still greater progress in this direction.

Since the introduction of the metal truss, the form of trussing has undergone very marked changes due not only to progress in manufacture and in facilities for work in the field, but also to wider experience and the better understanding of theory. And so, as has been said before, many of the early ingenious systems bearing the names of their inventors were gradually abandoned until now only two of them are used, the Warren and the Pratt systems; the so-called sub-divided Pratt system, usually being given preference for long spans. The earlier through-bridges had trusses generally with parallel chords; later, trusses with parabolic top chords for independent spans, when the spans were of sufficient length, came into almost exclusive use. The Bismarck Bridge in North Dakota is one of the many examples of this change. Three four-hundred-foot spans, built in 1883 with trusses of double intersection Howe system with parallel chords, were replaced in 1905 by spans of the same length having trusses of the sub-divided Howe system and parabolic top chords (Fig. 42).

The United States, because of the rapid growth of its railways and the magnitude of its streams, offers the greatest opportunity of any country for the development of the science and knowledge of bridge-building. Unfortunately, we have now entered upon an era of standard specifications and each engineering society of any size is bent upon compiling its own. So that an engineer desiring to secure somewhat better material for his structure is met by objections from the manufacturer who claims that if the standard specifications of such and such

FIG. 42.

Bismarck Bridge, North Dakota.

society are good enough the engineer should be content with them. This automatically arrests any effort on the part of the contractor to produce better material than what is known by him as "commercial product" and thus progress in the manufacture of materials of higher grade quality for bridge work is retarded. The material is not improving in quality—it is even deteriorating. Standard specifications are an advantage in many cases, but not in regulating the product of industries which are still almost in their infancy and in process of development.

But the modern-bridge engineer is far from having the

privileges of Pontifex Maximus. Leupold quotes the following interesting description of those privileges:

"What great consideration the bridges and their conservation occupied with the ancients and especially with the Romans is sufficiently illustrated by the following:

"That the office of building and conserving such (bridge) should be given and entrusted to a person bearing the title of a Pontifex Maximus, which person was *exempt* above all other persons and even possessed the highest direction of the then pagan service of God, and who completely possessed all power in religious matters to do and to let as he found fit. Yea, the position was so great and important that a great emperor, Augustus, and after him many other pagan and Christian emperors, attached this title to their imperial dignity. And while the Christian emperors did not apply such office in a pagan way, they utilized it as Christians to represent by it the highest person in the spiritual as well as in the wordly society. For, a Pontifex Maximus was bound by no law and did not have to give account of his doings to the people nor to the Council; could not be called for penalty; no one dared attack him by word; kept such dignity and office during his lifetime; no one equal to him was appointed; could let himself be carried into the Capitolium, which was not permitted to any other man and besides was an asylum for persecuted criminals."

And if we wish to know what requirements one had to possess to be a bridge engineer two hundred years ago, one should read in Leupold's work the following:

"Since bridge-building is to be considered as being among the foremost and most important works of man, in which all human understanding, wisdom, experience, in fact, all arts and sciences, must coöperate, such an 'Architecto' must not only be experienced in arithmetic and geometry, so as to be able to measure precisely the length, breadth and depth of a stream, to plat all this correctly and accurately on a geometrical plan, to estimate quantities of all materials, as stone, timber, lime, iron work, and finally, to determine the cost of construction; but he must also be a good physicist, to well understand all properties of the materials of construction and distinguish between their faults and merits, particularly, which wood is best, when it should be cut and to what purpose each kind serves; also the

properties of the water, of the ice, how and where it exerts its greatest force and how such a force can best be overcome; he must above all have a good understanding of the ground and bottom of the river in which the piles or piers are to stand; he must also have a sufficient knowledge of mechanics, partly to indicate or apply machinery for procuring, lifting and lowering the large beams, piles, stones, etc., and for driving piles by means of convenient hammers; partly to be able to indicate various methods for lifting the water out of cofferdams, or to drive the cofferdams themselves, and to lift the water from around the piers or where it is desired to reach the ground; and, above all, he must be a good carpenter and stone mason, both being equally the foremost and principal part in the building of a bridge; because if the bridge is entirely of wood, then it falls entirely to the carpenter; if, however, it is of stone, then has the carpenter one of the most important works to perform in building scaffolding and centres, and the stone mason must not let his art be without experience either; and the knowledge of the law of gravity is here mainly required so one would know how the bodies press and where the greatest effort comes and where those forces can best be resisted; to sum up, there are so many things required that space is here too small to touch upon all of them."

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Samuel Latham Mitchill—a Father in American Chemistry.—The Chandler Medal for 1922 has been awarded to Edgar Fahs Smith by Columbia University. At the conferring of the medal, Doctor Smith delivered an address on "Samuel Latham Mitchill—a Father in American Chemistry" (*Jour. Ind. Eng. Chem.*, 1922, xiv, 556–560). Mitchill was a native of Long Island, was educated in medicine at Edinboro, and became professor of chemistry in Columbia in 1792 at the age of 28 years. He was an ardent antiphlogisto-

nist and a pioneer in the study of the application of chemistry to the arts and to sanitation. He also made contributions to geology, mineralogy, and ichthyology, assisted in the preparation of the United States Pharmacopœia, and founded *The Medical Repository* which became a journal of general science and contains many of the earliest American contributions to chemistry. In addition to his scientific and educational work, Mitchill served as a member of the New York legislature and represented that state in the United States House of Representatives and Senate. J. S. H.

Rapid Electrolysis without Rotating Electrodes.—GRAHAM EDGAR and R. B. PURDUM, of the University of Virginia (*Jour. Am. Chem. Soc.*, 1922, xliv, 1267–1270), have devised a method for the rapid determination of metals by electrolysis with stationary electrodes. By use of a simple glass apparatus, the solution is stirred indirectly by a current of air during the electrolysis. A 110-volt lighting circuit, reduced by resistance lamps, was used as a source of current. As much as 4 decigrams of metallic copper were deposited quantitatively in 20 minutes. The method was used for the quantitative determination of silver, lead, copper, cadmium, iron, zinc, cobalt, and nickel. J. S. H.

Colorimetric Determination of Hydrogen Peroxide.—M. L. ISAACS, of the University of Cincinnati (*Jour. Am. Chem. Soc.*, 1922, xliv, 1662–1663), describes the following reaction of hydrogen peroxide. Thirty c.c. of water, 10 c.c. of 5 per cent. solution of citric acid, and 1 c.c. of dilute solution of hydrogen peroxide are mixed; and 1 c.c. of 10 per cent. solution of ammonium molybdate is slowly added. A yellow color develops. This reaction may be used for the colorimetric determination of hydrogen peroxide. The yellow solution is diluted to a volume of 50 c.c., and is compared in a Duboscq colorimeter with a standard solution of potassium chromate. This solution contains 0.4 gram of potassium chromate per litre, and is standardized against the color yielded by hydrogen peroxide of known concentration. J. S. H.

Functions of Aluminium in Living Matter.—JULIUS STOKLASA (*Umschau*, 1922, xxvi, 134–135) has studied the functions of aluminium in living matter. Thus aluminium protects plants from the injurious action of an excess of iron. By virtue of this property, aluminium promoted the growth of plant life during the carboniferous period, and thus made possible the coal deposits. In conjunction with iron and manganese, aluminium plays a part in the formation of the pigments in the blossoms of plants. The blue, violet, red, and blue-green pigments in birds and beetles owe their origin in part to the action of aluminium. This element is also present in the blood. J. S. H.

THE STABILITY OF ATOM NUCLEI, THE SEPARATION OF ISOTOPES, AND THE WHOLE NUMBER RULE.*

BY

WILLIAM D. HARKINS, Ph.D.

Department of Chemistry, University of Chicago.

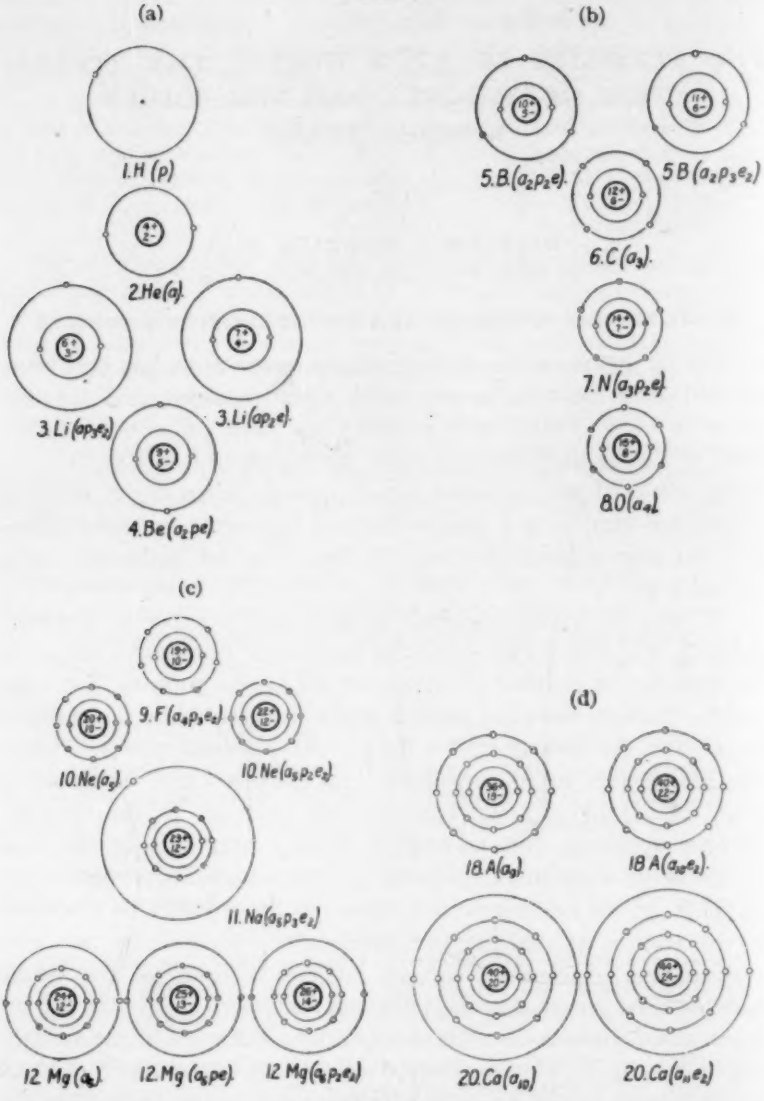
26. THE NUCLEUS CONSIDERED AS A PROTON-ELECTRON AGGREGATE.

Up to this point the nucleus of a complex atom has been considered to be built up largely from alpha particles, and for this point of view considerable evidence has been presented. However, it will be of advantage from the standpoint of simplicity to study some of the relations which emerge when the nucleus is considered simply as a proton-electron aggregate, without reference to any groups into which they may be gathered inside the nucleus.

If only the lighter elements up to atomic number 16 are considered, it is found that while the number of protons in the atom is equal to the number of electrons, all of the protons, but only half of the electrons, are present in the nucleus, while the remaining half of the electrons form the planetary system outside. Thus the magnesium atom consists of 24 electrons and 24 protons, with all of the protons, but only 12 electrons in the nucleus. Strictly speaking, this relation is exactly true only in the case of the most abundant isotope of an even-numbered element. In the case of the odd-numbered elements, the number of electrons in the atom is an odd number which is not divisible by two, and the number of electrons in the nucleus is equal to the whole number next larger than half the total number. Thus the aluminium atom consists of 27 protons and 14 electrons in the nucleus together with 13 planetary electrons. This last number is equal to 27 minus 14, or 13, which is the net positive charge on the nucleus. Fig. 4 illustrates these numerical relations in a number of typical cases.

* Continued from page 211, vol. 194, August, 1922.

FIG. 4.



Diagrammatic representation of the composition of atoms. Each small open circle represents a planetary electron, and the figures inside the heavy circles give the number of protons (+) and of electrons (−) in the nucleus. The isotopes of lithium (Li), boron (B), neon (Ne), magnesium (Mg), argon (A), and calcium (Ca) are given. The second isotope of argon and the first of calcium are isomeric, since both have the composition $+_{40}\ -_{40}$, and the nuclei of their atoms are practically isobaric (at. wt. = 40). While the planetary electrons are given in a plane, they may be supposed to be arranged in a three-dimensional space.

27. STABILITY CONDITIONS AND RELATIONS FOR ATOM NUCLEI.

Astronomers have had great difficulty in the exact treatment of the three-body problem, and it is readily seen that all known complex nuclei contain, according to our present theories, more than this number of particles. If the uranium nucleus is supposed to be made up of protons and electrons, there are 238 of the former and 146 of the latter, or 384 in all. Even if only the alpha particles assumed to be present are considered, it is evident that there are 59 particles at least to be taken into account. The problem of nuclear stability is therefore one in which the number of bodies is very large, so no exact mathematical treatment of the subject is possible. However, the writer has pointed out the most general relations which must be fulfilled in order that an atom may be stable. These general relations were found by the application of a general principle whose applicability was pointed out in 1916.[29]

This general principle may be stated as follows:

The relative abundance of the different atomic species in known materials—including the material of the meteorites, the surface of the earth, and what is known of the composition of the stars and nebulæ—*gives an index which points out the most important of the stability relations of the different types of atoms.* In addition to the data on the relative abundance of different atomic species, we have for the heaviest or radioactive atoms, data concerning their actual stability with respect to disintegration. It should be kept in mind, too, that there are different types of stability; thus a nucleus may be very stable with respect to an alpha disintegration, and quite unstable with reference to a beta disintegration, and *vice versa.* Also there may be instability with reference to the emission of protons, possibly with a concomitant emission of electrons, as in the disintegration experiments of Sir Ernest Rutherford.

The most general of all of the stability conditions may be expressed as follows:

[29] HARKINS: *J. Am. Chem. Soc.*, 39, 856-877 (1917); *Proc. Nat. Acad. Sciences*, 1, 186-214 (1916).

In JOURNAL OF THE FRANKLIN INSTITUTE, 193, pp. 603, 604, and pp. 109 and 110 of a book on Isotopes, the relations listed here have been published without any reference to their earlier publication by the present writer.

1. *No atom has been discovered in which there is less than one electron to each two protons,* so it may be concluded that the most general stability condition is: *No nucleus is stable unless the number of electrons it contains is equal to or greater than half the number of protons.* It is of extreme interest that in most atomic species which are found in meteorites and in the earth's crust, the number of nuclear electrons is exactly equal to half the number of protons. Furthermore, in the alpha particle, from which all atom nuclei are almost entirely built, the numerical relations are also exactly these simple ones.

The second stability relation is given as follows:

2. *As the nucleus becomes more positive with reference to its net content of positive electricity, it is essential for stability that it shall become more negative with reference to its relative content of negative electrons.*

In addition to the above three relations of primary importance, there are others which are less general, and these will be outlined later.

This principle indicates that for each element there is only a limited range of relative negativeness in which atoms can have enough stability to exist, which means that the number of stable isotopes is not very large, and is limited to certain range of atomic weights, or of isotopic numbers.

The third stability principle relates to the negative electron content of the nucleus:

3. *The number of negative electrons in most atom nuclei is even.* Thus there are about 40 times as many atoms in the earth's crust which contain an even number of nuclear electrons, as there are of those in which this number is odd. In the meteorites the ratio is 33 to 1.

Thus, *nuclei, or groups of electrons and protons in nuclei, which contain an odd number of negative electrons, are in general much less stable than those which contain an even number.*

While the abundance relation stated above refers to the occurrence of individual atoms, it is apparent that the stability principle deduced from it should have an application concerning the number of the various types of atomic species in existence. *Thus there should be many more atomic species* (isotopes) *with an even than with an odd number of nuclear electrons.* This principle has received an ample verification since its first announcement.

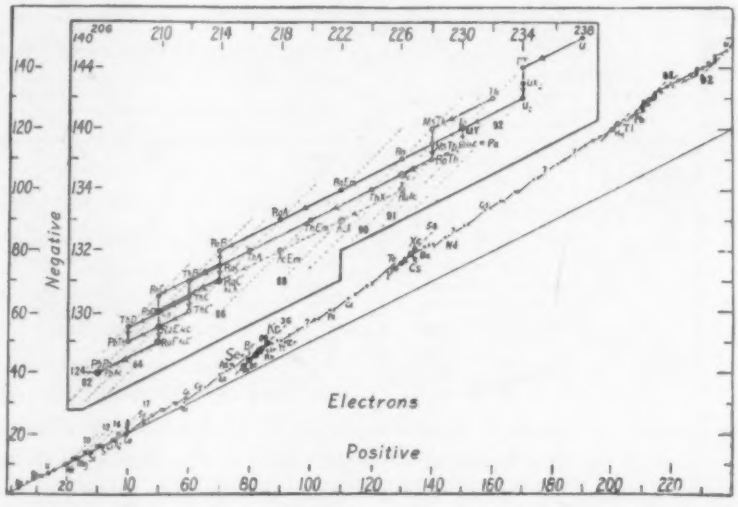
NOTATION.

P	atomic weight, or number of positive electrons.
M	atomic number, or positive charge on nucleus.
N	$P-M$, or number of negative electrons in the nucleus.
n	isotopic number.
p	a positive electron.
e	a negative electron.
a	an alpha particle.
pe	a neutron.

Using the above notation, the first general stability relation discussed above may be expressed in a general form as follows:[30]

In complex nuclei the number of electrons is never less than half the number of protons, or the ratio N/P is never less than

FIG. 5.



one-half. Thus the number of protons is never larger than twice the number of electrons, or P/N is never greater than 2.

Since $P-N=M$ it is evident that *the number of positive electrons in an atom* (or the atomic weight) *is always equal to or greater than twice the net positive charge on the nucleus* (atomic number), so $P/M=2$, or $M/P=\frac{1}{2}$.

The relation between the number of positive and negative electrons in atom nuclei is shown in Fig. 5. It may be seen that while the light atoms lie very nearly on a line of a slope equal to $\frac{1}{2}$, the number of negative electrons steadily increases above

[30] Harkins: *J. Am. Chem. Soc.*, **42**, 1965–85 (1920).

the value given by this line as the nucleus becomes heavier. The radioactive elements are plotted in the upper part of the diagram, which shows that during a series of alpha changes the elements remain upon a line with a slope of ½, or exactly that for the light atoms.

The number of negative electrons in light nuclei is equal to (or only slightly greater than) the atomic number (Fig. 7), while the number of positive electrons is twice the atomic number (Fig. 6). The two figures (6 and 7) exhibit the important relation that

FIG. 6.

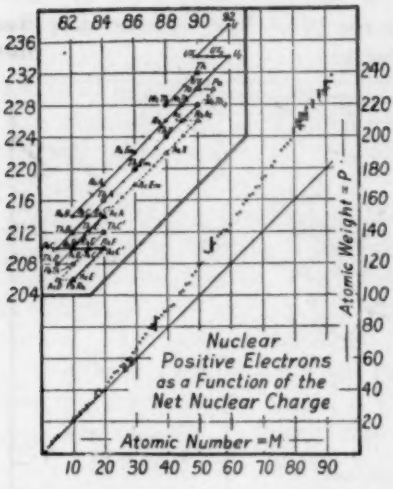
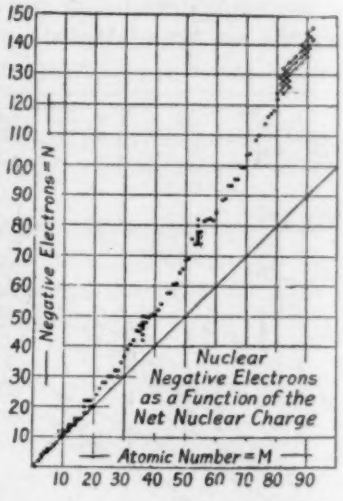


FIG. 7.



the number of electrons in any nucleus, in excess of the number represented by the inclined straight line, is the same in both figures (6 and 7), so in either figure the height of any point above the inclined line, represents the number of neutrons (pe) in the nucleus in excess of the composition represented by the formula $(p_2e)_M$. The number of neutrons found in this way will be designated later as the isotopic number of the atomic species.

18. THE ISOTOPIC NUMBER.

It is evident that so long as only one atomic species was known to exist for each of the 92 elements, that a single number for each element, the atomic number, was sufficient to designate all of the atomic species known. However, as soon as it was found that each element may consist of several atomic species, or

isotopes, it became evident that a second number was necessary. While the number usually chosen for this purpose has been the atomic weight, it is evident that there is another number which is more suited as a basis for the classification of isotopes. This number has been designated by the writer as the *isotopic number.** The isotopic number may be defined as the number of neutrons (pe) in a nucleus in excess of the composition represented by the formula $(p_2e)_M$. It was first made evident in the following way: If the number of positive electrons in the nucleus is represented on the X-axis, and the relative negativeness minus 0.5, or $(\frac{N}{P} - 0.5)$, is plotted on the X-axis, it is found that all atomic species lie either on the X-axis (isotopic number 0) or upon one of 54 equilateral hyperbolas (isotopic numbers 1 to 54), as is shown in Fig. 8. These hyperbolas are represented by the equation $P(\frac{N}{P} - 0.5) = 0.5\ n$, or $n = 2P\left(\frac{N}{P} - 0.5\right)$, so

$$n = P - 2M \quad (1)$$
$$n = 2N - P \quad (2)$$
$$n = N - M \quad (3)$$

Equation 1, which may be written $P = 2M + n$ shows that *the isotopic number is that number which, when added to twice the atomic number, gives the atomic weight.* Equation 2 indicates that it is also the *excess of twice the number of nuclear negative electrons over the number of protons,* and equation 3, that it represents the *excess of the number of nuclear negative electrons over the net positive charge on the nucleus.*

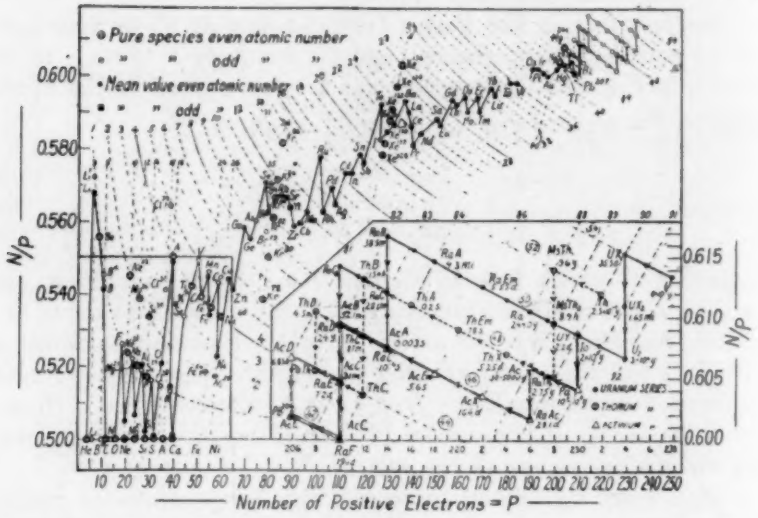
The lower right-hand corner of Fig. 8 represents the radioactive elements. It is evident that *in an alpha disintegration the isotopic number remains constant, while a single beta disintegration decreases the isotopic number by two.* Of these two units one is due to the decrease of N by one, and the other to the concomitant *increase* of M by one.

The addition of a negative electron to any nucleus would increase its isotopic number by two, but decrease its atomic

* When first used by the writer [*J. Am. Chem. Soc.*, **42**, 1971 (1920) and **37**, 1380, 1385, 1386, 1395 (1915)] the number was one-half that given in the later papers. It is evident that the half-values give the same system of classification, but involve the use of numbers which are not all integers. Masson [*Phil. Mag.*, **41**, 281–5 (1921)] has used the present system of notation.

number by one, while the addition of a positive electron would decrease its isotopic number by one, and increase its atomic number by one. The three isotopes of magnesium may be designated as Mg 12_0^{24}, 12_1^{25}, and 12_2^{26}, with the isotopic number (n) written as a subscript. While the atomic weight is given as a superscript, it is superfluous, since its value is always twice the atomic number (12 in this case) plus the isotopic number. The addition of a positive electron to the nucleus of Mg 12_2^{26} would give 13_1^{27}, which is aluminium. The addition of a negative electron to the nucleus of Ca 20_0^{40} would give K 19_2^{40}, and of a

FIG. 8.



second negative electron would give A 18_4^{40}, which is the most abundant isotope of argon. Thus the nuclei of the most abundant isotopes of calcium and argon, both with an atomic weight equal to 40, differ by 2 negative electrons, and in that the isotopic number of the former is 0, while that of the latter is 4.

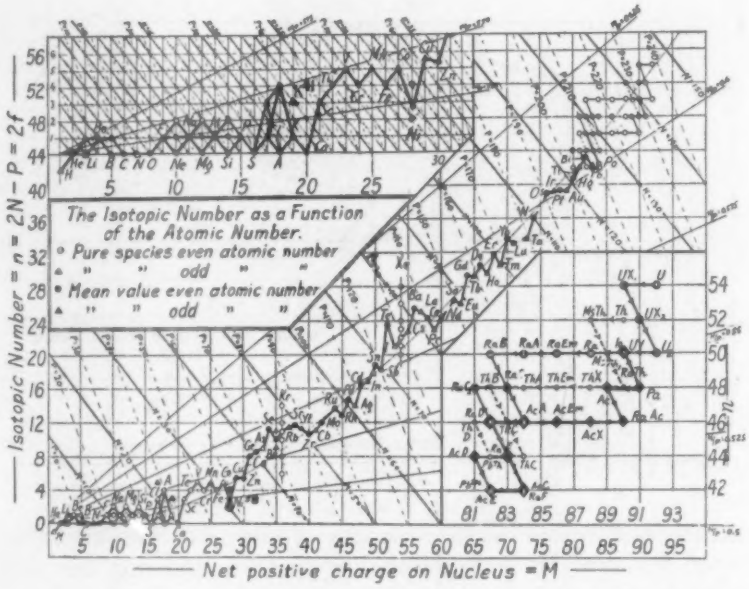
29. ISOTOPIC AND NEUTRONAL LINES.

A line upon which all of the isotopes of a single element lie in Fig. 8 or any other diagram, may be called an *isotopic line.* In the figure these are nearly vertical, but incline slightly to the right. A line upon which atomic species of a single isotopic number lie, may be called a *neutronal line,* since the number

of such a line gives the number of neutrons in the nucleus in excess of the normal composition represented by the formula $(p_2e)_M$.

The neutronal lines may be considered as representing levels, which in a radioactive series are related to the number of beta particles emitted by the nucleus. It is of interest that in the thorium and uranium disintegration series, and also in the actinium series, as given by most workers on radioactivity, all of

FIG. 9.


The Isotopic Number as a Function of the Atomic Number.
° Pure species even atomic number
▲ " " odd " "
• Mean value even atomic number
▲ " " odd " "
Isotopic Number = n = 2N − P = 2f
Net positive charge on Nucleus = M

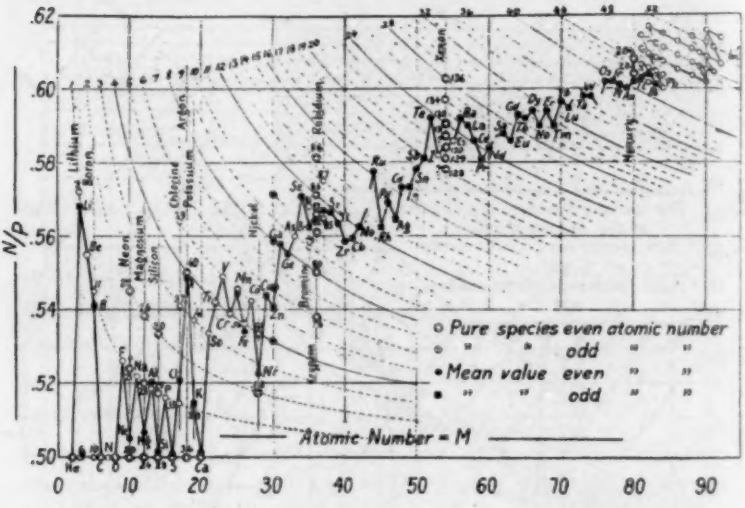
the neutronal lines, which represent paths of disintegration, have even numbers. The isotopic number of thorium is 52, which indicates that if thorium were to disintegrate completely into helium, the number of beta particles (cementing electrons) emitted would be 26, or in general the number of beta particles emitted in the complete disintegration into helium of any element whose isotopic number is divisible by 4, is one-half of the isotopic number.

In Fig. 9 the isotopic lines are vertical, and the neutronal lines are horizontal. In this plot isobaric atoms, such as Ca_0^{40} and A_4^{40}, lie on lines whose slope is -2, and those with a constant

number of nuclear negative electrons lie on a line whose slope is −1. The region of stability in which atoms exist has in this plot the general form of an hyperbola. The heavy lines in the radioactive portion of the plot represent disintegration series, but those in the other parts of the figure show merely the periodicity; mainly of the mean values.

Fig. 9 has the remarkable characteristic that it plots the values of five variables: n, M, P, N, and N/P, in a plane, and

FIG. 10.



that constant values for the first four of these variables are represented by straight lines which are parallel, and for the fifth by straight lines which radiate from the origin.

30. SECOND STABILITY PRINCIPLE: INCREASE OF THE RELATIVE NEGATIVENESS OF ATOM NUCLEI AS THE NET POSITIVENESS INCREASES.

The first stability principle states that the number of electrons in an atom nucleus is never less than half the number of protons, or the ratio N/P is always equal to, or greater than, ½. Now, the most abundant light atoms up to atomic number 20, are those in which this ratio has exactly the value 0.5, so it is of interest to inquire as to what values this ratio takes as the atomic number rises above the value 20. Fig. 10 shows the general variation of the ratio as the atomic number increases, and indicates that for

TABLE XVI A.

Values of the Relative Negativeness N/P of the Nuclei of Radioactive Atomic Species, together with the Isotopic Numbers.

Uranium Series in Order of Disintegration.

Element.	Net positive charge.	Atom.		Positive electrons.	Negative electrons.	α-Particles.	N/P	Electrons.		
								Cementing.	Excess.	Formula.
U.....	92	U	54	238	146	59	0.614	26	28	27
Th.....	90	UX_1	54	234	*144*	*58*	*0.616*	*26*	*28*	*27*
Bv.....	91	UX_2	52	234	*143*	*58*	*0.612*—	*25*	*27*	*26*
U.....	92	U_2	50	234	142	58	0.607	24	26	25
Th.....	90	Io	50	230	140	57	0.609	24	26	25
Ra.....	88	Ra	50	226	138	56	0.611	24	26	25
Nt.....	86	RaEm	50	222	136	55	0.613	24	26	25
Po.....	84	RaA	50	218	134	54	0.615	24	26	25
Pb.....	82	RaB	50	214	*132*	*53*	*0.617*	*24*	*26*	*25*
Bi.....	83	RaC	48	214	*131*	*53*	*0.612*	*23*	*25*	*24*
Po.....	84	RaC′	46	214	130	53	0.608	22	24	23
Pb.....	82	RaD	46	210	*128*	*52*	*0.610*	*22*	*24*	*23*
Bi.....	83	RaE	44	210	*127*	*52*	*0.605*	*21*	*23*	*22*
Po.....	84	RaF	42	210	126	52	0.600	20	22	21
Pb.....	82	RaG	42	206	124	51	0.602	20	22	21

Secondary Branch of Uranium Series

Pb.....	82	RaB	50	214	*132*	*53*	*0.617*	*24*	*26*	*25*
Bi.....	83	RaC	48	214	131	53	0.612	23	25	24
Tl.....	81	RaC_2	48	210	*129*	*52*	0.614_3	*23*	*25*	*24*
Pb.....	82	End	46	210	128	52	0.609_6	22	24	23

TABLE XVI B.

Thorium Series in Order of Disintegration.

Th.....	90	Th	52	232	142	58	0.612	26	26	26
Ra.....	88	$MsTh_1$	52	228	*140*	*57*	*0.614*	*26*	*26*	*26*
Ac.....	89	$MsTh_2$	50	228	*139*	*57*	*0.610*	*25*	*25*	*25*
Th.....	90	RaTh	48	228	138	57	0.605	24	24	24
Ra.....	88	ThX	48	224	136	56	0.607_1	24	24	24
Nt.....	86	ThEm	48	220	134	55	0.609_1	24	24	24
Po.....	84	ThA	48	216	132	54	0.611_1	24	24	24
Pb.....	82	ThB	48	212	*130*	*53*	0.613_2	*24*	*24*	*24*
Bi.....	83	ThC	46	212	*129*	*53*	0.608_6	*23*	*23*	*23*
Po.....	84	ThC′	44	212	128	53	0.603_8	22	22	22
Pb.....	82	PbTh	44	208	126	52	0.606	22	22	22

Secondary Branch of Thorium Series

Pb.....	82	ThB	48	212	*130*	*53*	0.613_2	*24*	*24*	*24*
Bi.....	83	ThC	46	212	129	53	0.608_6	23	23	23
Tl.....	81	ThD′	46	208	*127*	*52*	0.610_3	*23*	*23*	*23*
Pb.....	82	End?	44	208	126	52	0.606—	22	22	22

atoms of moderate abundance the range in the values of N/P is much greater for light than for heavy atoms. Thus the two isotopes of lithium exhibit a difference of slightly more than seven-hundredths, while in the whole radioactive region the extreme range thus far found is less than one-third as great. Thus there is a broad stability band, narrowing toward the right, extending from the lower left to the upper right-hand corner of the figure.

For the purposes of the present discussion Fig. 10 should be a three-dimensional diagram, the third dimension being taken

TABLE XVI C.

Actinium Series (Assumed to be Derived from U^2).*

Element.	Net positive charge.	Atom.		Positive electrons.	Negative electrons.	α-Particles.	N/P	Electrons.		
								Cementing.	Excess.	Formula.
Th.....	90	UY	50	230	140	57	0.608_8	24	26	25
Pa.....	91	Pa	48	230	139	57	0.604_2	23	25	24
Ac.....	89	Ac	48	*226*	*137*	*56*	0.606_2	*23*	*25*	*24*
Th.....	90	RaAc	46	226	136	56	0.602—	22	24	23
Ra.....	88	AcX	46	222	134	55	0.603_6	22	24	23
Nt.....	86	AcEm	46	218	132	54	0.605_4	22	24	23
Po.....	84	AcA	46	214	130	53	0.607_5	22	24	23
Pb.....	82	AcB	46	*210*	*128*	*52*	0.609_5	*22*	*24*	*23*
Bi.....	83	AcC	44	210	127	52	0.605	21	23	22
Po.....	84	AcC′	42	210	126	52	0.600	20	22	21
PbAc....	82	AcE	42	206	124	51	0.602	20	22	21
Pb′.....	82	AcD	44	206	124	51	0.602	20	22	21

P = no. of positive electrons. N = no. of negative electrons.

* E. Q. Adams considers that the atomic weight of lead derived from actinium is 207. If this is the case all of the values for the actinium series should be recalculated.

to represent the abundance of the atomic species. The details of this three-dimensional plot will be discussed later, but it is apparent that there is a general increase in the value of N/P as M increases. It is also apparent that for any single isotopic number the value of the ratio *decreases* as the atomic number increases, so the second stability principle indicates that there should be a rapid general increase in the isotopic number with the atomic number. Since the principal isotope of element 92 has an isotopic number 54, the mean increase is 0.6 of an isotopic number per atomic number.

The variation of N/P in a single series of atomic species

may be exhibited by a consideration of the principal uranium, or radium, disintegration series. In order to secure increasing values in general, the series will be considered in the reverse order of disintegration, but without assuming at all that the nuclei could be actually built up in this way. Beginning with radium G, isotopic number 44, the value of N/P is 0.602. This decreases very slightly to 0.600 in the alpha addition to radium F, and then increases rapidly in two beta additions to 0.605 and 0.610. Then by one alpha addition it falls to 0.608, and by two beta additions rises to 0.612 and 0.617. Then in five alpha additions it falls to 0.615, 0.613, 0.611, 0.609, and 0.607, and by two beta additions rises to 0.612 and 0.617. Then in five alpha additions it falls to 0.614, the value for the principal isotope of uranium. There is thus in any series (in its reverse order) the same gradual fall of N/P in a series of alpha changes, as is found in the light elements when the atomic number rises and the isotopic number remains constant. In a beta addition in this region the increase of N/P is about 0.005, while among the light atoms a beta addition would increase the ratio much more markedly. Thus between Ca_0^{40} and A_4^{40} the increase per beta particle would be 0.025, or five times as great. It is obvious that in the actual disintegration of the radioactive elements the ratio *increases* by about 0.002 in an alpha disintegration, and *decreases* by about 0.005 in a beta disintegration. Thus UX_1 ($N/P = 0.616$) and RaB ($N/P = 0.617$) have about the same value of the ratio, since there are two beta and five alpha disintegrations between the two.

31. THE RELATIVE STABILITY OF RADIOACTIVE ISOTOPES AS RELATED TO THE RATIO OF NEGATIVE AND POSITIVE ELECTRONS IN ATOM NUCLEI.

According to an empirical rule discovered by Fajans the period (half life) of the atomic species in any set of isotopes decreases with falling atomic weight for species which undergo alpha disintegration, and increases with atomic weight for those which undergo beta disintegration. The second stability principle gives to this rule a theoretical form, as follows: *The greater the ratio* $\frac{\text{Total number of negative electrons}}{\text{Total number of positive electrons}}$ *in the nucleus the more rapid is a β-disintegration which lowers the ratio, and the less rapid is an α-disintegration which raises it, provided the net posi-*

tive charge on all of the nuclei considered is the same, that is, when isotopes alone are considered.[31]

According to Kossel[32] the Fajans rule is related to the number of cementing electrons in the nucleus, or more exactly to the value of f in the atomic weight equation of Harkins and Wilson in its simpler form:

$$P = 2(M + f).$$

It will be seen, however, that the relation to the ratio N/P is both simpler and more exact.

It will be seen that for any set of isotopes *the more positive the nucleus in the sense of the ratio P/N of positive to negative electrons, the more unstable it is with respect to the emission of positive alpha particles. Also the more negative the nucleus with respect to the ratio N/P of negative to positive electrons,*

[31] The general idea on which the above relationship is based, is that as it becomes more negative in the sense that N/P increases, the nucleus binds positively charged particles more firmly, and negatively charged particles less firmly. While if isotopic atoms alone are considered, that is nuclei of constant net charge, there are only two complete exceptions to the relationship in about thirty-seven disintegrations, there is an apparent, but not actual, reversal of the rule when the nuclear charge varies. There are also three partial exceptions to the rule, in that members of the radium and actinium series of the same N/P ratio, have different periods, but this is to be expected as the result of more specific influences. These statements are based on the idea that the actinium series springs from U_{II}. Thus the reversal occurs in successive α-disintegrations, since as is well known, the period and, therefore, the stability of the nucleus, with reference to the giving off of α-particles, decreases rapidly as the disintegration proceeds. That is, as it becomes *less* positive, both with respect to its net charge and with reference to the ratio N/P, the nucleus holds each succeeding positive particle *less* firmly, so as the relative negative electron-content increases, the stability with reference to the retention of positive α-particles decreases. In the radium series there are five, and in both the actinium and the thorium series as now known, four such successive α-disintegrations. There is also a reversal with respect to the loss of negative electrons, since the second β-disintegration is always more rapid than the first in the case of two successive changes of this nature, even though the nucleus is becoming more positive by the loss of its β-particles. There is thus an irregular, but periodic, variation in the stability of nuclei in any one series. As an hypothesis to account for this fact it has been suggested in an earlier paper that the negative cementing electrons are grouped in pairs, and that in the nucleus the α-particles are grouped in aggregates containing four or five (and probably other numbers, as low as one) such particles in each group, and that each aggregate becomes less stable as it decreases in size. (*Phys. Rev.*, **15**, 88 (1920)).

[32] Kossel: *Physik. Z.*, **12**, 265–9 (1919).

the more unstable it is with respect to the emission of negative beta particles.

The existence of the relation of Fajans is very strong evidence in favor of the idea that this ratio is of prime importance in determining the stability of atom nuclei. Other evidence of the same import will be found in the later sections on the abundance relations of the various atomic species. Since there are also other factors which are of extreme importance in determining stability, it is not to be expected that the Fajans relation will prove to be perfectly general; indeed, it seems remarkable that it holds at all exactly for atomic species which have descended from different ancestors, such as uranium and thorium. The great advantage of the radioactive evidence over that found by considering the relative abundance of the different atomic species, lies in the fact that the former includes information with respect to the type of instability involved.

32. THIRD, FOURTH, AND FIFTH STABILITY PRINCIPLES: THE HIGH RELATIVE FREQUENCY OF OCCURRENCE OF EVEN NUMBERS OF ELECTRONS AND PROTONS IN NUCLEI.

The third stability principle, already given, states that most atom nuclei contain an even number of negative electrons. The fourth principle is of somewhat less importance, and is based upon the statistical fact that there are many more atom nuclei and nuclear groups of electrons and protons, which contain an even number, than there are of those which contain an odd number of protons. As a stability principle this may be stated:

4. *Atom nuclei, and groups of protons and electrons in atom nuclei, are in general more stable when they contain an even, rather than an odd, number of protons.*

The fifth principle of stability is a combination of the third and the fourth, and has been extensively discussed in the first part of the present paper, where it was found that *elements of even atomic number are much more abundant than those of odd atomic number.*

5. Since most atom nuclei contain an even number (N) of negative electrons, and also most nuclei contain an even number (P) of positive electrons, it is evident that $P - N$ or M, the net positive charge on the nucleus must also be in general an even number, so *atoms whose net positive nuclear charge is an even number, are in general much more stable than when this*

charge is an odd number. Extensive evidence in support of this general relation will be found in Sections 12 to 18, inclusive, of the present paper. It may be recalled that in the meteorites elements of even atomic number are 70 times as abundant as those of odd atomic number.

Table XVII exhibits the remarkable fact that 94.6 per cent. of all of the atoms in the meteorites contain an *even number* of both nuclear *electrons* and *protons,* and so the net number of positive charges on the nuclei is also an even number.

TABLE XVII.

Atomic Percentage of the Atomic Species in the Meteorites (350 Stone to 10 Iron) in Which the Number of Nuclear Negative Electrons (N), of Protons (P) and of Net Charges on the Nucleus (M = P − N) is an Even Number.

Element.	Isotopic Number.	Atomic per cent.	P-N (=M)	P	N	N/P	Order of Abundance.
O	0	53.16	8	16	8	0.5	1
Si	0	13.82	14	28	14	0.5	2
Fe	4	11.76	26	56	30	0.536	3
Mg	0	9.86	12	24	12	0.5	4
Mg	2	1.65	12	26	14	0.538_6	5–6*
S	0	1.46	16	32	16	0.5	8
Fe	2(?)	1.03	26	54	28	0.518_5	10
Ca	0	0.95	20	40	20	0.5	11
Ni	2	0.50	28	58	30	0.517	13
Ni	4	0.26	28	60	32	0.533	14
Cr	4	0.13	24	52	28	0.539	15
Ti	4	0.005	22	48	26	0.542	20
Total	=	94.585 per cent.					

* Mg^{25} and Mg^{25} are present in about the same atomic percentage and are together fifth and sixth in order of abundance.

Thus the first four atomic species in order of abundance are all of the type represented by this table, and the fifth place is occupied by one of these together with another species of the same abundance.

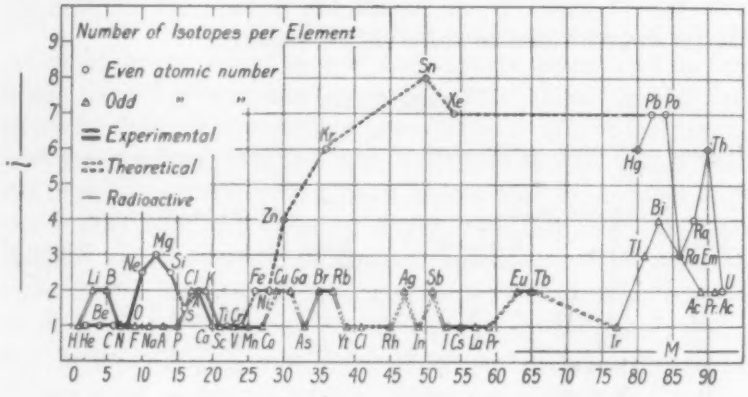
The percentage of atoms in which the number of nuclear negative electrons is even, is higher than that given above by 2.1 per cent. or the total percentage is 96.7, while the percentage in which $P - N$ or M is even, is 98.

33. INDICATION OF THE FIFTH STABILITY PRINCIPLE THAT THERE ARE MORE ISOTOPES OF ELEMENTS OF EVEN THAN OF ODD ATOMIC NUMBER.

The hydrogen-helium theory, developed in 1915, indicated that there should be a marked difference in stability between the

elements of even and of odd atomic number, and extensive evidence was presented to show that the atoms of the elements of even atomic number are much the more stable.[33] It is apparent that there should be more isotopes of those elements which have the more stable atoms, so it follows that there should be more isotopes of elements of even than of odd atomic number. That this is true for the radioactive elements was pointed out in 1917 by N. F. Hall.[34] A year earlier the writer[33] showed that the atomic weight relations give strong evidence that between atomic

FIG. 11.


Number of Isotopes per Element
Even atomic number
Odd " "
Experimental
Theoretical
Radioactive
H He C N F Ne A P Ca Sc V Mn Co As Yt Cl Rh In I Cs La Pr Ir M
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90

numbers 28 and 82 the number of isotopes is large. However, the above principle made evident that it was to be expected that *only the elements of even atomic number* would contain a large number of isotopes in this region.[35]

Several of the facts, which have now become known as the result of experiment, were pointed out earlier by the writer by the use of the general theory and the mean atomic weights. These were first, that the region of abundant isotopes would begin, for

[33] Harkins: *Proc. Nat. Academy of Sciences*, **1**, 186–214 (1916); *J. Am. Chem. Soc.*, **39**, 856–79 (1917), and sections 12 to 16 of the present paper.

[34] Hall: *J. Am. Chem. Soc.*, **39**, 1616–19 (1917).

[35] Harkins: *Ibid.*, **42**, 1956–97 (1920). It is of interest that this idea that the isotopes of the elements of even number and not those of odd number in this region would be particularly numerous was contained in this paper, which was presented before the discovery of any isotopes in this region.

the even-numbered elements, at atomic number 28 or 30. Element 28 is the first element of even number in which the more abundant isotope has a lower atomic weight than the less abundant, and element 30, zinc, is the first in the series in which the number of isotopes rises to 4. It was also predicted that lithium and boron would be found to consist of two isotopes each, and thus in the limited section between atomic numbers 2 and 8 the number of isotopes is greater for elements of odd than for those of even number. This prediction was verified later by the experiments of Dempster, Thomson, and Aston.

The validity of the general principle is exhibited clearly by Table XVIII and Fig. 11, which list the number of isotopes thus far found experimentally in this region.

TABLE XVIII.

Number of Isotopes of Elements of Atomic Numbers between 29 and 81.

Even Atomic Number.			Odd Atomic Number.		
Atomic Number.	Element.	Number of Isotopes.	Atomic Number.	Element.	Number of Isotopes.
30	Zinc	4	33	Arsenic	1
36	Krypton	6	35	Bromine	2
50	Tin	8	37	Rubidium	2
54	Xenon	7	53	Iodine	1
80	Mercury	7 (or 6)	55	Cæsium	1
	Total =	32			7
Average number =		6.4			1.4

Thus there are 6.4 isotopes per element when the atomic number is even, and only 1.4 when it is odd, so far as the present data are concerned. *These results are a remarkable confirmation of the hydrogen-helium theory of the writer, since all of these relations were developed from the theory and the mean atomic weights before the discovery of the confirmatory evidence.*

34. THE NEW PERIODIC SYSTEM AS RELATED TO THE THIRD STABILITY PRINCIPLE.

In the periodic system of Mendelejeff, which relates to the properties of the outer atom, the number of elements per period is

2, 8, 18, and 32. In the new periodic system, which relates to the composition and stability of atom nuclei, the principal periodicity is of 2 units, which corresponds to the number of charges on the alpha particle, and there is a second periodicity of 4, corresponding to the mass of the alpha particles, but this second periodicity is much less apparent. It is evident that the third stability principle, which states that one of the most important of all stability conditions is that the most stable atoms contain an even number of negative electrons, indicates a periodicity of 2. It may be shown that this periodicity may be represented by a double network, such is exhibited graphically in Fig. 12, in which the abscissæ give the atomic, and the ordinates the isotopic numbers. Atomic and isotopic numbers which are even, are represented by heavy, while the odd numbers are represented by light lines. It will be seen that nearly all of the atomic species (46) lie at the junction of either the heavy lines, or else at the junction of the light lines, and that only very few (7) lie where heavy and light lines cross. Any atom represented by a point where heavy lines meet each other, or where light lines meet each other, contains an even number of nuclear negative electrons, while any atom at the junction of light with heavy lines contains an odd number of such electrons. The figure represents a limited part of that given in Fig. 9, which should be consulted for the general relations, but is on too small a scale to properly show the periodicity exhibited here, *which is that of periods of two along both axes; that is both with respect to the atomic and the isotopic numbers.* The isotopes which lie at intersections of heavy and light lines are not only less numerous, but on the whole they are less abundant than those which are at the intersection of lines which are alike.

The importance of the third stability principle is illustrated also by Table XIX, which lists the number of nuclear negative electrons in the most abundant isotope of each element thus far investigated by the positive ray method.

So far as present data indicate there are eight times as many elements in which the most abundant isotope contains an even number, as there are of those which contain an odd number of nuclear negative electrons.

TABLE XIX.

The Number of Negative Electrons in the Nucleus of the Most Abundant Isotopes of Each Element Thus Far Investigated by the Positive Ray Method.

Atomic Number.	Element.	Number (N) of Negative Electrons in the Nucleus.	
		Even Number.	Odd Number.
2	Helium	2	
3	Lithium	4	
4	Beryllium		5
5	Boron	6	
6	Carbon	6	
7	Nitrogen		7
8	Oxygen	8	
9	Fluorine	10	
10	Neon	10	
11	Sodium	12	
12	Magnesium	12	
14	Silicon	14	
15	Phosphorus	16	
16	Sulphur	16	
17	Chlorine	18	
18	Argon	22	
19	Potassium	20	
20	Calcium	20	
28	Nickel	30	
30	Zinc	34	
33	Arsenic	42	
35	Bromine	44	
36	Krypton	48	
37	Rubidium	48	
53	Iodine	74	
54	Xenon		75
55	Cæsium	78	

The above facts lead to the hypothesis that relative instability is the result of the presence of an odd number of negative nuclear electrons, either an instability of the nucleus, or an instability of the group containing the odd electron, this group being essential for the formation of the nucleus. In order to test this hypothesis we may turn to the radioactive atomic species (Table XX), where the stability of the nuclei is known in terms of their average periods of disintegration. It should be remarked that in considering nuclear instability mention should be made of the type of instability, which in the radioactive series would be instability with reference to beta particle emission.

TABLE XX.

Effect of an Odd Number of Negative Nuclear Electrons in Producing Nuclear Instability.

Atomic Species.	N (=even).	N=even Average Life.	N=odd Average Life.	N (=odd).	Atomic Species.
UX_1	144	35.5 days	1.65 min.	143	UX_2
$MeTh_1$	140	9.6 years	8.9 hours	139	$MsTh_2$
RaD	128	24 years	7.2 days	127	RaE

The above comparison indicates an extremely striking difference in each case between the periods, and shows that in each case the disintegration is much more rapid when the nucleus contains an odd number of electrons; about 50,000 times more rapid in the first case, 18,000 in the second, and 2200 in the third. The effect is not so striking in cases where there is a splitting of the series, but is in all cases in the proper order in the thorium and uranium series. It seems likely that in such a complex structure as the nucleus of a heavy atom there may be some exceptions to this general relationship, but none has been found thus far. Unfortunately, the atomic weight of none of the members of the actinium series is known, so the relations in that series cannot be listed. It is evident that they are not quite so simple as in the other two series.

35. HYPOTHESIS THAT THE NEGATIVE ELECTRONS IN ATOMIC NUCLEI, AND IN PROTON-ELECTRON GROUPS IN ATOM NUCLEI, ARE MOSTLY ARRANGED IN PAIRS.

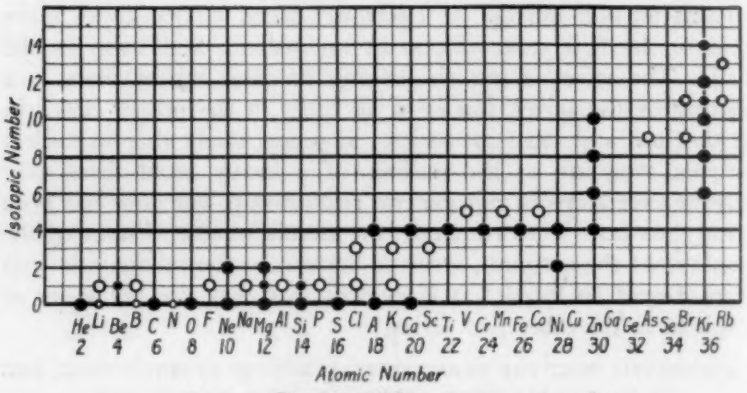
When the above facts are taken into consideration, and especially since there seem to be two negative electrons in the alpha particle—the most important group in nuclear building—it seems that the following statement is justified: *The negative electrons in atom nuclei seem to be usually associated in pairs.*[36] This is not unlike the relation found by Lewis for the planetary electrons in molecules, since in only about one in a thousand molecules is there an odd number of planetary electrons. A later discussion will consider the relation of these pairs of nuclear negative electrons to the formula groups other than the alpha particle which seem to occur in the nucleus. The most prominent of these formula groups seem to be those of formulas p_3e_2 and p_2e_2, where p stands for a proton, and e for a negative electron. Both of these

[36] Harkins: *Physical Review*, 15, 77 (Feb., 1920).

formula groups contain a single pair of negative electrons, just as is the case with the alpha particle.

The rarity of atoms in which the number of negative nuclear electrons is odd is well illustrated by the meteorites. In no case does the average result of the quantitative analyses, as represented by any collected set of data, indicate the presence of any element whose most abundant isotope shows an odd value for N, and the only atomic species of this class which seem to be present are Mg_1^{25} (1.64 per cent.), and Si_1^{29} (about 1.5 per cent.) which together make up about 3 per cent. of the atoms of the material.

FIG. 12.


Isotopic Number
0
2
4
6
8
10
12
14
He Li Be B C N O F Ne Na Mg Al Si P S Cl A K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr Rb
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Atomic Number

The new periodic system.

Thus about 97 per cent. of the atoms have an even number for N. In the earth's crust, only about one atom in 50 has an odd value for N.

Possibly the most beautiful illustration of the effects of this tendency for N to be an even number is to be found in the atomic weights of the most abundant atomic species in each element of odd atomic number. When M is odd, since $P - N = M$, it is evident that either P or N, but not both, must be odd, so if, according to rule, N is even, then P or the *atomic weight must be odd.* Now it is very remarkable that the atomic weights of all of the elements from 3 to 27 inclusive, with the exception of nitrogen, are odd numbers, and the rule holds that P is odd for all of the individual isotopes as well, with the exception of those, such as B_0^{10} and Li_0^6, which occur only in extremely small percentages. The rule also holds for the isotopes found by Aston: Br_9^{79}, Na_1^{23},

Rb_{11}^{85}, Rb_{13}^{87}, Cs_{23}^{133}, K_1^{39}, K_3^{41}, Br_{11}^{81}, As_9^{75}, I_{21}^{127}, Cl_1^{35}, Cl_3^{37}, and possibly a Cl_5^{39}.

Additional evidence in favor of this hypothesis is found in the fact [36] that *whenever beta disintegrations of the radioactive atoms occur, there are usually two successive emissions of a beta particle, and in the remaining cases there is one beta emission just before, and a second just after, the ejection of an alpha particle.*

36. SECOND SYSTEM OF CLASSIFICATION OF ATOMIC SPECIES.

Before considering further the relation between nuclear stability and the isotopic number it is essential to outline a second method for classifying isotopes. This has already been suggested under the experimental correlations relating to the oddness or evenness of the numbers representing positive or negative nuclear electrons, and is given a definite form in Table XXI.

TABLE XXI.

Classification of Atomic Species According to Even and Odd Number of Electrons.

		Abundance in Earth's Crust.	Atomic Percentage Meteorites.
Class I.	N = even, P = even.....	86.9	93.2
Class II.	N = even, P = odd	11.2	2.0
Class III.	N = odd, P = odd	2.3	3.2
Class IV.	N = odd, P = even.....	0.0	0.0

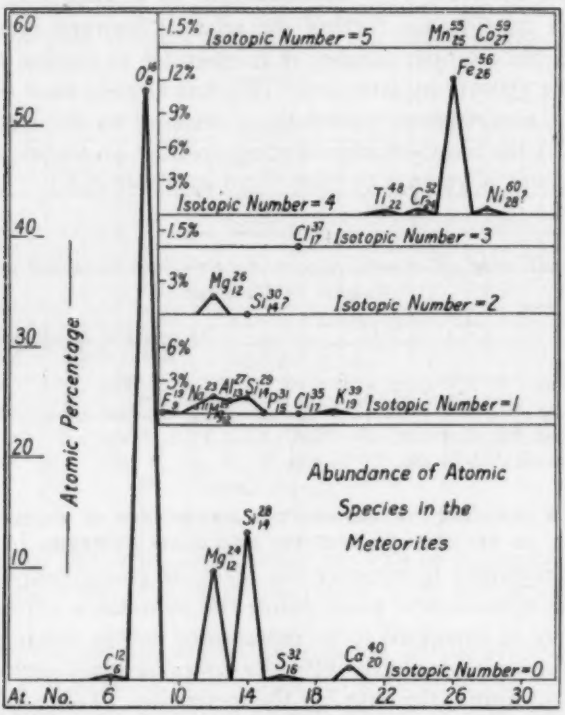
37. THE NEW PERIODIC SYSTEM AND THE ABUNDANCE OF ATOMIC SPECIES AS RELATED TO ISOTOPIC AND CLASS NUMBERS.

It is important to consider the N/P, M plot given in Fig. 10 as lying in a horizontal plane, while the abundance of the atomic species may be imagined to be represented by the vertical coördinates. On account of the difficulty of presenting such a three-dimensional figure, the data for the meteorites (Table XXII) are given in Fig. 13. This gives the third dimension for Figs. 5 to 10, and also 12. A similar plot for the crust of the earth (Table XXIII) is presented in Fig. 14.

The form of the three-dimensional plot may be imagined by supposing Figs. 13 and 14 to lie in a horizontal plane, but that the peaks which represent the abundance of the atoms are turned on the isotopic lines as axes until they stand vertically above the latter. While the isotopic lines are not equidistant in these figures this is due to the differences necessary to prevent a confusion of

the peaks, so they should be imagined as spaced at equal distances. It should be remembered that since these two figures give the values for elements 2 to 30, they represent practically 100 per cent. of the material. The rectangle in the lower left-hand corner of Fig. 8 includes this region. Thus this rectangle includes all of the high peaks of abundance, while to the right and above this rectangle the peaks are so low as to be invisible

FIG. 13.

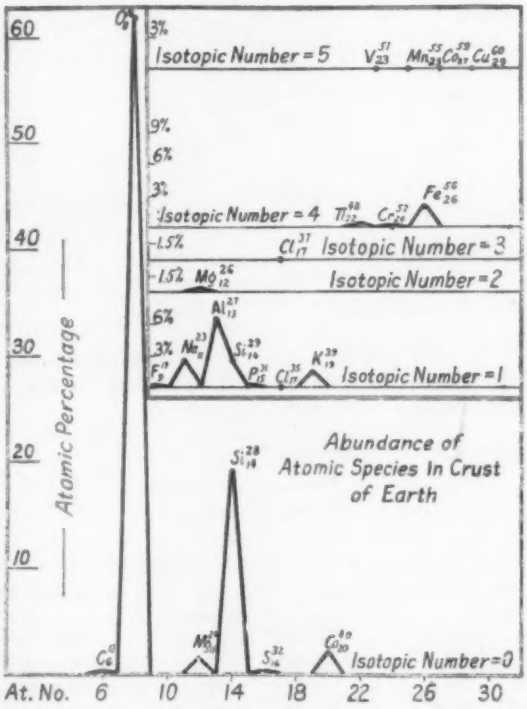


above the plane in a plot of ordinary dimensions. This is more apparent if it is considered that the total height of all of the several hundred peaks outside this rectangle, when added together (Fig. 8), is less than one five-hundredth of the height of the oxygen peak alone.

In Fig. 10 isotopic number 0 is represented by the X-axis, while all other values from 1 to 54 are represented by curves which have almost exactly the form of equilateral hyperbolæ. Along any of these curves the abundance of the isotopic species

first rises and then falls. Thus, for example, on the curves for isotopic number 1, no atomic species are known above lithium (0.013 per cent. in the earth's crust). Going from this species downward toward the right the abundance increases to 0.030 for fluorine, 2.27 for sodium, 5.55 for aluminium, 1.22 for potassium, and beyond this no species are known. The figures for the meteorites are more in point, since they are affected less by segre-

FIG. 14.


Isotopic Number = 5
Isotopic Number = 4
Isotopic Number = 3
Isotopic Number = 2
Isotopic Number = 1
Isotopic Number = 0
Abundance of Atomic Species In Crust of Earth
Atomic Percentage
At. No. 6 10 14 18 22 26 30

gation of the material, and the figures are: Lithium, boron, and fluorine not abundant enough to be given; sodium, 0.62; aluminium, 1.21; phosphorus, 0.06; potassium, 0.11; with no more species known. Oxygen, the most abundant species of isotopic number 0, and iron, the most abundant of isotopic number 4, are both near the middle of the general band of stability, and on the whole this is what may be expected, though individual stability influences may sometimes make a considerable shift in the position of the highest peak.

TABLE XXII.*

Abundance of the Atomic Species in the Meteorites as Classified According to Their Isotopic and Class Numbers.

(Atomic Percentage.)

Isotopic Number = 0.
Class Number = I.

Atomic Number.	Symbol.	Per cent.
6	C	0.12
8	O	53.16
12	Mg^{24}	9.86
14	Si^{28}	13.82
16	S	1.46
20	Ca	0.97
Total		79.39

Class Number = IV.

7	N	0.00

Isotopic Number = 1.
Class Number = II.

Atomic Number.	Symbol.	Per cent.
11	Na	0.62
13	Al	1.21
15	P	0.06
19	K	0.11
Total		2.00

Class Number = III.

12	Mg^{26}	1.65
14	Si^{30}	1.53
Total		3.18

Isotopic Number = 2.
Class Number = I.

Atomic Number.	Symbol.	Per cent.
12	Mg^{25}	1.65
14	Si^{29}	
28	Ni^{58}	0.50
Total		2.15

Isotopic Number = 3.
Class Number = II.

Atomic Number.	Symbol.	Per cent.
17	Cl	0.00
19	K	0.005
21	Sc	0.00

Isotopic Number = 4.
Class Number = I.

Atomic Number.	Symbol.	Per cent.
22	Ti	0.005
24	Cr	0.13
26	Fe^{56}	11.76
28	Ni^{60}	0.26
Total		12.93

Isotopic Number = 5.
Class Number = II.

Atomic Number.	Symbol.	Per cent.
23	V	0.00
25	Mn	0.06
27	Co	0.04
Total		0.10

It is worthy of note that the above percentages, together with that of the lower isotope of iron probably of isotopic number 2, whose percentage is not included, since it is uncertain as to its exact isotopic number, make up 99.9 per cent. of all of the material of the meteorites, and the similar atomic species, atomic numbers up to 28 and isotopic numbers—1 to 5, make up 99.9 per cent. of the earth's surface, which indicates that *no increase in the ratio of electrons to protons (N/P) is able to sufficiently stabilize atoms with a positive nuclear charge greater than 28 as to make such atomic species any considerable factor in the abundance relations. The important feature of this relation is that the abundance does not fall off gradually but suddenly, and remarkably enough the fall in abundance comes just beyond nickel, while nickel and zinc are the first of the elements in the region of abundant isotopes.* All abundant atomic species have isotopic numbers 4 or less.

* Revised from a table given by the writer in *Phil. Mag.*, xlii, Sept., 1921, pp. 317 and 318.

TABLE XXIII.

Abundance of the Atomic Species in the Earth's Crust as Classified According to Their Isotopic and Class Numbers.

Isotopic Number = 0.
(N/P = 0.5.)
Class Number = I.

Atomic Number.	Symbol.	Per cent.
6	C	0.047
8	O	61.94
12	Mg^{24}	1.40
14	Si^{28}	19.06
16	S	0.034
20	Ca	1.93
Total		84.41

Class Number = IV.

3	Li^{6}	0.0005
5	B^{10}	....
7	N	....
Total		0.0005

Total Isotopic Number = 1 = 84.41

Isotopic Number = 1.
Class Number = II.

Atomic Number.	Symbol.	Per cent.
3	Li^{7}	0.009
5	B^{11}	0.00x
9	F	0.086
11	Na	2.64
13	Al	6.43
15	P	0.089
17	Cl^{35}	0.025
19	K	1.42
Total		10.70

Class Number = III.

12	Mg^{25}	0.22
14	Si^{29}	(?) 2.04
Total		2.26

Total Isotopic Number = 2 = 12.96

Isotopic Number = 2.
Class Number = I.

Atomic Number.	Symbol.	Per cent.
12	Mg^{26}	0.21
14	Si^{30}	?
26	(Fe^{56})	?
28	(Ni^{58})	0.01
Total		0.22

Isotopic Number = 3.
Class Number = II.

Atomic Number.	Symbol.	Per cent.
17	Cl^{37}	0.007
21	Sc	0.00000
19	K	0.07
Total		0.077

Isotopic Number = 4.*
Class Number = I.

Atomic Number.	Symbol.	Per cent.
22	Ti	0.28
24	Cr	0.017
26	Fe^{56}	1.88
28	Ni^{60}	0.005
30	Zn^{64}	0.000x
Total		2.19

Isotopic Number = 5.
Class Number = II.

Atomic Number.	Symbol.	Per cent.
17	Cl^{39}	.....
23	V	0.009
25	Mn	0.037
27	Co	0.000
29	Cu	0.0006 (?)
Total		0.047

Isotopic Number = 6.
Class Number = II.

Atomic Number.	Symbol.	Per cent.
30	(Zn^{66})	(0.0000x ?)
32	(Ge^{70})	.....
36	Kr^{78}	.....

* It should be noted that in isotopic number 4 the relations of isotopic number 0 are repeated, but with a much smaller abundance. Thus both have a high abundance relative to the adjacent atomic numbers; in both Class I is prominent, and while Class IV has not yet been found in isotopic number 4, it may be present, but only in a very minute quantity. Isotopic number 5 repeats in a lesser degree the relations of isotopic number 1, again with the omission of the secondary class, Class III. While the numbers given in the table may be changed slightly in a few cases by the discovery of new isotopes, the atomic weight and abundance relations indicate that *such changes will not affect the general relations* presented.

35. THE PERIODICITY OF FOUR WITH RESPECT TO THE ISOTOPIC NUMBER.

Fig. 13 exhibits the interesting relation that superimposed upon the periodicity of 2 with respect to the isotopic number as shown in Fig. 12, there is a periodicity of 4. This is shown plainly by Table XXIV.

TABLE XXIV.

Periodicity of 4 in the Variation of the Abundance of Atomic Species in the Meteorites with the Isotopic Number.

Isotopic Number.	Atomic Percentage.
0	79.39
1	5.18
2	2.15
3	0.005
4	12.16
5	0.10
6	0.000

While this periodicity may become obscured as the isotopic number increases, by the periodicity of 2 upon which it is superimposed, the table makes it evident that the former periodicity in abundance is very marked so long as the isotopic number is low. Fig. 12 shows that the number of isotopes also rises at isotopic number 4. The rise in abundance is very great between isotopic numbers 3 and 4; thus the abundance for isotopic number 4 is 2400 times what it is for the next lower number. Table XXIII shows that a similar table for the earth's crust would indicate a like periodicity, though the variation is not so marked, being represented by the factor 30 instead of 2400 between isotopic numbers 3 and 4. This illustrates what has been pointed out in other cases, that the chemical and physical segregation of the materials in the earth's crust makes all of the periodic relations less sharply defined than they are in the meteorites.

(To be continued.)

Rôle of Manganese in Plants.—J. S. MCHARGUE, of the Kentucky Agricultural Experiment Station (*Jour. Am. Chem. Soc.*, 1922, xliv, 1592–1598), finds that manganese in conjunction with iron functions in the synthesis of chlorophyll. Manganese is therefore required by plants in order that they may assimilate carbon. Manganese possibly also plays a rôle in the synthesis of the proteins. Lack of manganese produces a chlorotic condition of the plant and cessation of growth. J. S. H.

PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATES OF HONORARY MEMBERSHIP, MAY 17, 1922.

At the Stated Meeting of the Committee on Science and the Arts, held January 4, 1922, the following resolutions were adopted:

"*Resolved*, That The Franklin Medal be awarded to Dr. Ralph Modjeski, Civil Engineer, of New York City, New York, in recognition of his signal achievements as a designer and builder of structures, mainly bridges, many of them epoch-marking in the history of the engineering profession, beautiful as well as useful, involving on the part of the designer vision, courage and technic of the highest order."

"*Resolved*, That The Franklin Medal be awarded to Sir Joseph John Thomson, of Cambridge, England, in recognition of the immeasurable service he has rendered to the world as teacher and leader of thought in that domain of science especially related to a fundamental knowledge of electricity and the constitution of matter."

CORRESPONDENCE.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY — JANUARY 12, 1922.

Dr. Ralph Modjeski,
818 Widener Building,
Philadelphia, Pa.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in physical science and technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

> "That The Franklin Medal be awarded to Dr. Ralph Modjeski, Civil Engineer, New York City, New York, in recognition of his signal achievements as a designer and builder of structures, mainly bridges, many of them epoch-marking in the history of the engineering profession, beautiful as well as useful, involving on the part of the designer vision, courage and technic of the highest order."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation

to come to the Institute on the afternoon of Wednesday, May 17th, to receive this medal and certificate from our President, Dr. Walton Clark.

I am

Respectfully,

(Signed) R. B. OWENS,
Secretary.

RBO:H

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818 Widener Bldg.,
Philadelphia, Pa.,
January 16, 1922.

DOCTOR R. B. OWENS, *Secretary,*
The Franklin Institute,
Philadelphia, Penna.

MY DEAR SIR:

I received your communication of January 12th and I wish to say that I consider the award of The Franklin Medal to me as the greatest honor that has ever been conferred upon me during my professional life.

I shall, of course, come to the Institute on the afternoon of Wednesday, May 17th, as requested. I shall then perhaps be able to express more fully my high appreciation of this award.

Very sincerely yours,

RM MLS (Signed) RALPH MODJESKI.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY JANUARY 31, 1922.

Sir Joseph John Thomson, O.M., F.R.S., LL.D., Ph.D., D.Sc.,
Trinity College,
Cambridge, England.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in physical science and technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

> "That The Franklin Medal be awarded to Sir Joseph John Thomson, of Cambridge, England, in recognition of the immeasurable service he has rendered to the world as teacher and leader of thought in that domain of science especially related to a fundamental knowledge of electricity and the constitution of matter."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on the afternoon of Wednesday, May 17th, to receive this medal and certificate from our President, Dr. Walton Clark.

I am Respectfully,

(Signed) R. B. OWENS,
Secretary.

RBO:H

TRINITY LODGE, CAMBRIDGE,
March 1, 1922.

DEAR DR. OWENS:

Would you be kind enough to convey to the members of The Franklin Institute my grateful thanks for the signal honour they have paid me by conferring upon me The Franklin Medal. It is a great delight to me to receive a medal associated with the name of the Founder of Electrical Science. I wish I could come over to receive it, but I am obliged by statute as Master of the College to be in residence in term time so that the only times I am free are those when everybody is like myself, taking a holiday.

The pleasure the medal gave me has been enhanced by the fact that the announcement of it came from one whom I am proud to claim as an old pupil.

With very kind regards,

Yours very sincerely,

(Signed) J. J. THOMSON.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

APRIL 4, 1922.

OFFICE OF THE SECRETARY

Sir Auckland Geddes, Ambassador Extraordinary
and Plenipotentiary of His Britannic Majesty,
British Embassy, Washington, D. C.

YOUR EXCELLENCY:

I have the honour to inform you that The Franklin Institute has awarded to Sir Joseph John Thomson, O.M., F.R.S., LL.D., Ph.D., D.Sc., Master of Trinity College, Professor of Physics, Cambridge University, England, The Franklin Medal, founded for the "recognition of those workers in physical science or technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications." The award is minuted as follows:

> "That The Franklin Medal be awarded to Sir Joseph John Thomson, of Cambridge, England, in recognition of the immeasurable service he has rendered to the world as teacher and leader of thought in that domain of science especially related to a fundamental knowledge of electricity and the constitution of matter."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on the afternoon of Wednesday, May 17th, to receive this medal and certificate from our President, on behalf of your Government, for Sir Joseph.

A second medal has been awarded to Dr. Ralph Modjeski, Civil Engineer. The award to him is minuted as follows:

> "That The Franklin Medal be awarded to Dr. Ralph Modjeski, Civil Engineer, New York City, New York, in recognition of his signal achievements as a designer and builder of structures, mainly

bridges, many of them epoch-marking in the history of the engineering profession, beautiful as well as useful, involving on the part of the designer, vision, courage and technic of the highest order."

It is hoped that it will be agreeable to you and to Dr. Modjeski to be guests of honour at a dinner to be given on the same evening by our President.

I am,

Your Excellency's very humble servant,

(Signed) R. B. OWENS,

RBO : H *Secretary.*

BRITISH EMBASSY
Washington

APRIL 6, 1922.

DEAR SIR:

With reference to your letter of April 5th, enclosing the invitation of The Franklin Institute to Sir Auckland Geddes, I have to inform you that His Excellency is at present absent from Washington, but on his return on the 12th instant I shall not fail to bring to his attention your letter under reference.

Yours very truly,

(Signed) D. N. MACKEEN.

R. B. OWENS, ESQ., *Secretary,*
The Franklin Institute,
Philadelphia, Pa.

BRITISH EMBASSY
Washington

April 27, 1922.

DEAR MR. OWENS:

In confirmation of our telephone conversation of the other day, I have to inform you that events outside the control of the Ambassador will prevent his acceptance of your courteous invitation of the 5th. His Excellency will, however, be very glad to delegate one of the senior members of this Embassy to accept the medal on behalf of Sir Joseph Thomson in his place, and as soon as I know who is to go I shall inform you.

Yours sincerely,

(Signed) H. V. TENNANT.

R. B. OWENS, ESQ., *Secretary,*
The Franklin Institute,
Philadelphia, Pa.

Telegram from His Excellency Sir Auckland Geddes to Dr. R. B. Owens, Secretary, dated May 16, 1922:

Owing to unforeseen circumstances I have delegated Mr. R. L. Craigie, first secretary His Majesty's embassy, to receive Franklin Medal on May 17th in place of General Bethell. GEDDES.

STATED MEETING

WEDNESDAY, MAY 17, 1922

3.30 O'CLOCK

PROGRAMMME

PRESENTATION OF

THE FRANKLIN MEDAL

AND

CERTIFICATE OF HONORARY MEMBERSHIP

TO

MAJOR GENERAL H. K. BETHELL

C.B., C.M.G., C.V.O., D.S.O.

BRITISH EMBASSY

WASHINGTON, D. C.

ON BEHALF OF HIS BRITANNIC MAJESTY'S GOVERNMENT

FOR

SIR JOSEPH JOHN THOMSON

O.M., F.R.S., LL.D., PH.D., D.SC.

CAMBRIDGE, ENGLAND

PRESENTATION OF

THE FRANKLIN MEDAL

AND

CERTIFICATE OF HONORARY MEMBERSHIP

TO

RALPH MODJESKI, D.ENG.

NEW YORK CITY

PRESENTATION TO

THE INSTITUTE

OF A PORTRAIT OF

WALTON CLARK, M.E., D.SC.

PAPERS

ELECTRON THEORY OF SOLIDS

SIR JOSEPH JOHN THOMSON

O.M., F.R.S., LL.D., PH.D., D.SC.

READ BY JOSEPH S. AMES, PH.D., LL.D.

THE JOHNS HOPKINS UNIVERSITY
BALTIMORE, MARYLAND

BRIDGES—OLD AND NEW

RALPH MODJESKI, D.ENG.

PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP TO DR. RALPH MODJESKI AND SIR JOSEPH JOHN THOMSON.

IN calling the meeting to order the President of the Institute announced that the business of the meeting would be the annual presentation of the Institute's highest award, The Franklin Medal, in recognition of distinguished scientific and technical achievements and recognized Dr. Joseph S. Ames, of the Johns Hopkins University, who made the following statement relative to the work of Sir Joseph John Thomson:

Mr. President: Your Committee on Science and the Arts, in its recommendations for the award of The Franklin Medals, has chosen two men whose names are known throughout the world. It is provided in the deed of gift that the medals shall be bestowed upon those "whose efforts, in the opinion of the Institute, have done most to advance physical science or its application." The first of these medals to be awarded to-day cannot, unfortunately, be handed directly to the recipient himself, since his duties at home make it impossible for him to be here. But we are honored by the presence of his fellow countryman, the official representative of Great Britain, who has graciously consented to accept, on behalf of his Government, The Franklin Medal awarded to Sir Joseph John Thomson, Master of Trinity College, Cambridge, and till recently Cavendish Professor of Experimental Physics. It is bestowed upon him in recognition of "the immeasurable service he has rendered to the world as teacher and leader of thought in that domain of science, especially related to a fundamental knowledge of electricity and the constitution of matter."

Sir Joseph John Thomson was born near Manchester in the year 1856, and received his early education in Owens College in

J. J. Thomson.

that city. From there he went to Cambridge and became a student at Trinity College, then, as now, the true home of men devoted to mathematics and physics. His career there was brilliant, as is shown by the number of prizes won and by the series of publications which then began. In 1880 he was Second Wrangler and also Second Smith Prizeman, being another of the long list of notable men who began their scientific lives with being Second Wrangler rather than first. His investigations, both theoretical and experimental, continued while he was Fellow of Trinity; and in 1884, when the Cavendish Professorship became vacant owing to the retirement of Lord Rayleigh, he was so obviously the man for this honored chair that he was urged, even by the Electors themselves, it is said, to become an official candidate. He was elected at once, and held the professorship until four years ago, thirty-four years of marvellous achievement. In 1918 he was elected Master of Trinity, and can now enjoy comparative leisure for his own studies.

His life has been marked by one honor after another. In 1884, the year he became Cavendish Professor, he was elected a Fellow of the Royal Society; universities and academies all over the world have honored him with degrees and election to their membership; in 1906 he was awarded the Nobel Prize—and, I may add, used the money which accompanies this award to supply the needs of the Cavendish Laboratory; and when the Order of Merit was instituted by the King he was one of those chosen as original members.

To all students of physics these honors bestowed upon Sir Joseph seem fit and proper. There is no living man to whom the science owes as much. He has profound mathematical insight and skill, an almost intuitive sense in directing the course ot experimental investigation, but, above all else, imagination and fertility of suggestion. The progress in physics and chemistry, for which, in the history of science, the past forty years will always be distinguished, centres around our knowledge of atoms and molecules. Thomson's experiments on the discharge of electricity through gases and his theories of the structure of atoms were the beginning of all this work, carried on first at the Cavendish Laboratory and later in every physical laboratory in the world. Through all these years Thomson has ever been at the very fore of the advancing multitude. His brilliancy in making

hypotheses to explain the facts revealed by experiments excites the admiration of every one, for they are hypotheses which bear fruit in further experiments. If any one requires abandonment or modification, he is ready with another which again guides the laboratory investigator. In the laboratory itself his work is directed by his unequaled knowledge of all the field of physics and lights the way for others. In addition to his personal services to science, he was, for the thirty-four years of his professorship, the director of the greatest physical laboratory in the world; a laboratory to which students from every country flocked. It was a delightful experience in those days to visit the Cavendish, as it was always called. In every room, in each corner of the room, there was an investigation in progress, often suggested by Thomson but always one with which he was familiar and to which he contributed much. In his own rooms he had his faithful Everett, a man of the greatest experimental skill, who received each day explicit directions and criticisms as to the fundamental work in which Thomson himself was engaged. If one looked far enough, it was discovered that the director did have an office, but what was notable was that its furniture consisted of a table and a stool, not a chair. Thomson would say that a chair tempted a man to sit down, while a stool inspired one to get up. As a lecturer in physics he, as a rule, talked about some mathematical problem in which at the time he was interested. His students were not men looking for degrees, but colleagues interested solely in advancing knowledge. With a group of men like that he could trust them to do their own reading and studying. No words can describe the full influence Thomson exercised upon his generation through his laboratory. The devotion of his associates was intense, there were affection and admiration. To everyone he was known as "J. J." Not that they addressed him as such, but whenever spoken of, then or now, no other name is used except this intimate one.

It would not be right to stop here with these general references to Thomson's services to science, without saying something of his part in the Great War. As the leading member of Lord Fisher's Inventions Board, all problems of a scientific nature were brought to him, and the help he rendered will never be known. I recall one incident which made a great impression upon me. You all remember Dürer's etching of the scholar in his study with a

lion lying at the doorway, ready to give a hint to any intruding visitor. Thomson has no lion at his door; but he has a wife who performs the lion's duties. During the war I was spending a few days in Cambridge with Thomson on business. One Sunday morning Lady Thomson invited us into the garden to see her flower beds; we knew what that meant, of course. But while we admired the daffodils and the narcissi, I glanced in the library to see how Thomson did his work. There he was sitting deep down in an easy chair, his feet high on the mantlepiece, now and then running his fingers through his long hair—any one who knows him has seen him do it an hundred times—and that was all. No, he was not dreaming, he was not even smoking, he was thinking, thinking for the good of the British Empire and America. It was a picture full of meaning.

It is a cause of deep regret to everyone here that Thomson cannot be present to-day to receive in his own hands The Franklin Medal. Of all living physicists he is the best known personally to Americans. Many of my countrymen have been students in his laboratory, and he has been in this country several times, often for prolonged visits. He and Lady Thomson have exercised most generously the great gift of hospitality towards American visitors. But while we all deplore his absence, it is a subject of congratulation to ourselves that the Medal will be handed for temporary keeping to one who is highly appreciative of the service rendered to the fighting front by those who, like Thomson, put in the hands of the Allies means of unmeasured value with which to save modern civilization.

It gives me great pleasure, Mr. Chairman, to present to you Mr. R. L. Craigie, First Secretary of the British Embassy of Washington, who will receive The Franklin Medal and transmit it to Sir Joseph J. Thomson.

The Chairman then said:

I desire, Mr. Craigie, before proceeding with the presentation of The Franklin Medal—which is the business which has brought us here—to say to you and to our other guests that the members of The Franklin Institute are highly sensible of the distinction added to their meeting by the presence of a representative of the Government of Great Britain.

Mr. Secretary, I have the honor, in the name of The Franklin Institute, and upon the recommendation of its Committee on

Science and the Arts, to present to you, for transmission through the Foreign Office of your gracious sovereign to Sir Joseph John Thomson, The Franklin Medal and Diploma, and a Certificate of Honorary Membership in The Franklin Institute. This award is made to Sir Joseph in recognition of his distinguished services to mankind rendered in the field of science. It is the highest honor in the gift of the Institute.

Mr. Craigie, in accepting the Medal and Diploma and the Certificate of Honorary Membership, said:

Mr. Chairman, Ladies and Gentlemen: It is a great privilege to be present on this important occasion and to accept, on behalf of Sir Joseph John Thomson, the beautiful Medal and the Certificate of Honorary Membership which The Franklin Institute has bestowed upon him. To meet the members of this famous institution of learning is in itself an event which I prize highly. To accept from you a token of honor bestowed upon a scientist whom we hold in the highest esteem and for whom there is world-wide admiration marks the occasion as one of special significance.

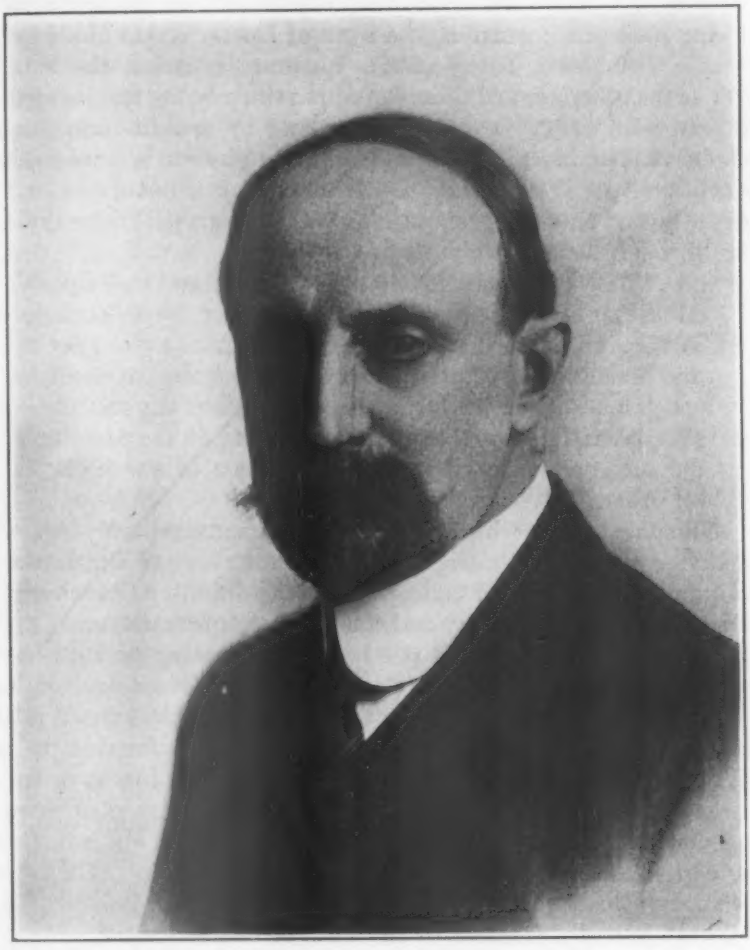
The Franklin Medal is awarded "to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications." Sir Joseph John Thomson has devoted to those very purposes a career which is full of enterprise and of valuable achievement and the fact that your choice should this year have fallen upon this distinguished physicist is not only, I know, deeply appreciated by him, but is regarded by his countrymen as a signal honor to the British Empire. His contributions to the advancement of those particular branches of science which he has made his own have been of incalculable value to his country and to the world. This recognition of his work by a distinguished American scientific body demonstrates once more that knowledge has no frontiers.

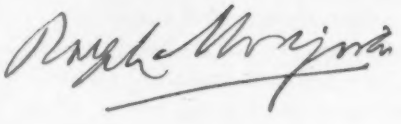
In this gathering of men of science I feel great diffidence in speaking of the achievements of science, but perhaps I may be permitted to refer to one aspect of scientific development which is of special interest to an Embassy and that is its influence on international relations. Behind all diplomacy lies the power to secure justice and that power must itself be based on knowledge and especially on those departments of knowledge which have been so much enriched by the researches and discoveries of Sir

Joseph John Thomson. In the great War, when you, and we, with all our allies, were called to defend freedom and the cause of right, we witnessed a most astounding development of the application of science to the methods of warfare. One of the most interesting instances of this development was in the department of optics which gave birth to the system of protective coloration, so largely utilized in the defense of vessels against submarines. Other applications of physical knowledge to submarine warfare spring readily to mind—the astonishing application of supersonic waves to determine the position of submarines, the use of electric detectors to indicate where and in what directions submarines were moving, or again in another field of military effort, the wonderful developments of sound ranging, or still again the almost incredible evolution of the science and art of flight in those few short years from August, 1914, to November, 1918. Here are perfect instances of the way in which knowledge created power in a moment of dire necessity.

Those were times of crisis, but the real, the great, the lasting achievement of science is not the aid it proffered in the day of battle, but the victories it wins for civilization and for peace. Inevitably, the war has left an aftermath of nationalism dangerously intense. Science, looking out on the world from its calm and exalted fastnesses, far removed from the dust of politics, should act as a corrective of that dangerous intenseness. The progressive advances of science are of world-wide concern and they so obviously transcend the limitations of frontiers that they seem to me to be capable of serving a most useful purpose in correcting the political perspective and in reminding us again, and yet again that we are a family of nations bound together by the closest ties of shared knowledge, the common basis of a common civilization. Directly and indirectly, science is called to play in the future an even greater rôle in the ceaseless struggle to preserve the world's peace.

The Franklin Institute, in awarding its medals independently of considerations of nationality, has taken a step which well illustrates the true relationship of science to the interests of mankind. Sir Joseph John Thomson has devoted his life to the work of adding rare precious stones to the walls of the rising temple of human knowledge, and it is with a feeling of gratitude and deep appreciation that His Majesty's Ambassador will forward this





medal of your award to the British Foreign Office for presentation to its distinguished recipient.

Doctor Onward Bates was then recognized and made the following statement concerning the work of Doctor Ralph Modjeski:

Mr. President: The Franklin Institute is known the world over as the promoter and guardian of physical science and its applications. Its policy is to encourage and to reward individuals who have done most in practically applying physical science to the benefit and use of mankind. On this occasion it honors an engineer who has made large contributions to the art of bridge building, through its action minuted as follows:

> "That The Franklin Medal be awarded to Dr. Ralph Modjeski, Civil Engineer, New York City, New York, in recognition of his signal achievements as a designer and builder of structures, mainly bridges, many of them epoch-marking in the history of the engineering profession, beautiful as well as useful, involving on the part of the designer, vision, courage and technic of the highest order."

This fair land in which we dwell has been marvellously blessed by divine providence. It is rich in natural resources which have been developed and used under favored conditions. Our citizens enjoy a degree of prosperity and comfort heretofore unknown, and when we seek the reason for this happy situation we find it is the providential outcome of science and industry. Of all the factors which enter into our civilization, facilities for transportation take rank among the first, perhaps are truly the first. Our country is enveloped in a network of railways, highways and footways furnishing the means of intercourse required in our manner of living and working. It would be difficult to overestimate the value to the nation of these different ways of communication. When the Delaware River Bridge is completed the people of Philadelphia will have practical evidence of the truth of this statement.

Engineers make roads, and in justice it must be added that they make some other things, and conversely, roads make engineers. Progress and experience go hand in hand and are reciprocal. Ours is a well-watered country, abounding with streams of all sizes, from rivulets to great rivers, all of which must be bridged when our people need roads across them. Rivers are the most formidable obstacles to be overcome in building roads. Some of the older ones in this audience may now remember the smallness

of the great bridges of fifty years ago, and how in succeeding years the engineers kept on building bigger and better bridges, each in turn of greater span and magnitude, thus setting a new mark of possibility.

Engineers who accomplish "impossible" feats through their talents and energy receive but slight recognition from their fellowmen who do not grasp the marvels of the accomplishment, and who take the engineers and their work as a matter of course. It may also be stated that engineers are proverbially modest, of which we have evidence near at hand this very day. Nevertheless, engineers are human and desire appreciation as much as others do. When The Franklin Institute confers its highest honor on an engineer who ranks as a great bridge builder, it honors itself by the act which rewards him in a manner that will give him greater satisfaction than any other recognition it could offer him.

The award of The Franklin Medal to Ralph Modjeski will be approved by engineers as having been justly earned by him, and it will also be considered a tribute to his profession.

Doctor Modjeski is a man of distinguished ancestry with natural talents which would make him personally distinguished in many different lines of endeavor, if able to give them the requisite attention. His life, as will be observed in a statement following, has been devoted with energy and industry to the particular work of designing and constructing bridges. It is to be regretted that the present opportunity is too limited to present other than the abbreviated notes which follow:

BIOGRAPHICAL NOTES OF RALPH MODJESKI.

Born in Cracow, Poland, January 27, 1861. Father's name, Gustav Sinnmayor Modrzejewski. Mother's maiden name, Helena Opid. She changed her name for convenience to that of Modjeska upon becoming a citizen of the United States. She made her home in America and was known as a dramatic artist. She died in April, 1908.

Doctor Modjeski was naturalized an American citizen in 1883 when he took out final papers. He attended Grammar and High Schools in Cracow up to 1876, at which time he came to America with his mother. In 1878 he went to Paris, France, and attended the Government College "École des Ponts et Chaussees." Graduated with degree of Civil Engineer at the head of his class in

1885. Came to America that summer and received his first engagement with George S. Morison, Civil Engineer, as Assistant Engineer on construction of the Union Pacific Bridge at Omaha, Nebraska; remained with Morison in various capacities until 1892. During these seven years occupied the position of Assistant Engineer on the Omaha Bridge, from 1885 to 1887, Inspector in the shops for bridge work, 1887 to 1889 at Athens, Pennsylvania; later, Chief Draftsman in Morison's office in Chicago, 1889 to 1891. During this time, in charge of design of the Mississippi River Bridge at Memphis. In 1891, Chief Inspector at the shops for the Memphis Bridge superstructure. In 1892, Assistant Engineer of construction of the Memphis bridge. Early in 1893 opened an office in Chicago as Civil Engineer in independent practice.

The first large bridge designed and constructed by Doctor Modjeski was the government bridge at Rock Island, Illinois, over the Mississippi River, which is a double track railway and highway structure. Then followed the reconstruction of the Bismarck Bridge at Bismarck, North Dakota, over the Missouri River, and later the Thebes Bridge, over the Mississippi River at Thebes, Illinois. This bridge was built under the firm name of Noble and Modjeski, the late Alfred Noble was one of the partners. The bridge was commenced in 1903 and completed in 1905. Then came the Columbia River Bridge and Willamette River Bridge, both in Oregon, for the Spokane, Portland and Seattle Railway. These bridges, costing over $4,000,000, were commenced in 1905 and completed in 1908. Then came the McKinley Bridge over the Mississippi River at St. Louis, the Columbia River Bridge at Celilo, Oregon, for the Oregon Trunk Railway, as well as other bridges for that company, including a 340-foot arch over the Crooked River. Almost immediately after came the Broadway Bridge over the Willamette River in the City of Portland, Oregon.

The bridges more recently completed are the new double-track railroad and highway bridge at Memphis, Tennessee; the single-track railroad and highway bridge over the Mississippi River at Keokuk, Iowa; the Metropolis Bridge over the Ohio River, Metropolis, Illinois. On this last-mentioned bridge, employed as Consulting Engineer in preparation of designs in conjunction with the late C. H. Cartlidge until his death, when the bridge was turned over to Doctor Modjeski.

Consulting Engineer in charge of the new double-track railroad bridge over the Ohio River at Cincinnati, now under construction for the Cincinnati Southern Railway.

Consulting Engineer for the New York, New Haven and Hartford Railroad on their Thames River Bridge at New London, Connecticut, recently completed. In charge of reinforcing of the present Poughkeepsie Bridge over the Hudson River at Poughkeepsie. Member of the Board of Engineers, appointed by the Dominion Government of Canada for the reconstruction of the Quebec Bridge, the longest span in the world. Has been member of that Commission ever since its formation in 1908. Made a complete report for the New York Bridge Department on the strength of the New Manhattan Bridge in New York (1909). The Cherry Street Bridge at Toledo, Ohio, which is a concrete arch structure, was built under his direction and the plans previously prepared by other parties were modified by him. During his independent practice, he has acted as Consulting Engineer for various railways and corporations on smaller structures. Prepared two sets of standard plans of spans from 10 feet to 250 feet in length for the Northern Pacific Railroad. In 1916 was member of a Commission appointed by the Public Service Corporation of New Jersey to determine the feasibility of a vehicular tunnel under the Hudson River, including preliminary plans and estimates. Designed and constructed fireproof warehouse for the Rock Island Arsenal at Rock Island, Illinois.

The aggregate cost of the completed structures in the above list exceeds forty million dollars.

In addition to the above, he was appointed Chairman of the Board of Engineers to report on the location and prepare preliminary plans for a bridge between Philadelphia, Pennsylvania, and Camden, New Jersey. The bridge involves an expense of some $28,000,000. The report was completed on June 9, 1921.

In 1911 received an honorary degree of " Doctor of Engineering " at the University of Illinois. He is a member of the following societies: American Society of Civil Engineers, The Engineering Institute of Canada, British Institution of Civil Engineers, American Institute of Consulting Engineers, Past President and member of the Western Society of Engineers, Society for Promotion of Engineering Education, The Franklin Institute of

Philadelphia, French Association of Engineers, Former Student of École des Ponts et Chausses.

Member of the following clubs: Engineers' Club of New York, Past President of the Chicago Engineers' Club, which was organized on his initiative, Union League Club of Chicago, South Shore Country Club of Chicago, Cliff Dwellers Club of Chicago. Has offices in Chicago and New York.

Member of the firm of Modjeski and Angier, Civil and Inspecting Engineers, who also have offices in Chicago, New York, Pittsburgh and St. Louis.

Married in 1885 in New York; has three children, a daughter and two sons, one of whom was in the U. S. Army service during the war.

The list of some of Doctor Modjeski's works which for the sake of brevity have been read by name only, indicates many communities who may claim him as a citizen, but engineers are not restricted to localities—their citizenship lies where their talents are most needed, and on this occasion Doctor Modjeski is a Philadelphian.

Mr. President, the task assigned me of introducing this modest gentleman and great engineer has been poorly performed, but this is of little consequence in comparison with the pleasure I entertain in presenting to you, Ralph Modjeski.

The Chairman, in presenting The Franklin Medal, Diploma and Certificate of Honorary Membership to Doctor Modjeski, said:

Doctor Modjeski, I have the honor, in the name of The Franklin Institute, upon the recommendation of its Committee on Science and the Arts, and in recognition of your distinguished services to mankind rendered in the field of science, to present to you The Franklin Medal and Diploma, and a Certificate of Honorary Membership in The Franklin Institute. This award is the highest honor in the gift of the Institute.

Doctor Modjeski, in accepting The Franklin Medal and Diploma, and Certificate of Honorary Membership, said:

Mr. President, it is not possible for me to frame adequate words to express my appreciation of the two great honors which you are conferring upon me. The more I feel, the less I can say, so please just let me say I thank you.

The President then requested Mr. Coleman Sellers, Jr., Vice-

DR. WALTON CLARK.

President of the Franklin Institute. From a portrait by Lazar Raditz, presented to the Institute by its Board of Trustees, Board of Managers and Officers.

president of the Institute, to take the Chair. Mr. Sellers recognized Mr. Nathan Hayward, who in presenting a portrait of Doctor Walton Clark, President of the Institute, said:

Mr. President, Ladies and Gentlemen, it is my great honour to speak for the Board of Trustees, the Board of Managers, and Officers of The Franklin Institute, in presenting to the Institute this portrait of our President, Doctor Walton Clark.

It is not customary for those making a present to praise it, but we who have had the pleasure of arranging this gift are greatly pleased with the results obtained by the artist, Mr. Lazar Raditz. We feel he has done a masterly work in recording for us so pleasingly the features of a gentleman, scholar and friend. As Mr. Raditz has said to me, the subject is one affording a rare opportunity for the exercise of artistic effort.

It would indeed be a pleasure and a delight to review at this time Doctor Clark's work in developing the Institute along the lines laid down by its Founders, but I know that he does not wish this done. He is satisfied with results and these can be seen and enjoyed from day to day.

> "In his own grace he doth exalt himself
> More than in your addition."

Members of The Franklin Institute, I present in the name of the Board of Trusteees, Board of Managers, and Officers of the Institute this portrait as doing Doctor Clark the highest honour within our power to bestow, and as a token of the love and admiration of his fellow-workers.

Mr. Sellers, in accepting the portrait, said:

Mr. Hayward, it gives me profound pleasure to accept for The Franklin Institute of the State of Pennsylvania this admirable portrait of our distinguished President.

I am sure that I speak for all the members of the Institute when I say that they highly appreciate this gift and cordially thank the Trustees, Managers and Officers for their thoughtful generosity.

The portrait will not only be a highly valued addition to our collection, but it is a well-deserved tribute to Doctor Walton Clark who has guided the activities of this old Institution for the last sixteen years, with unselfish devotion and conspicuous success.

The President then took the chair and recognized Doctor Joseph S. Ames, of the Johns Hopkins University, who read

the paper, "An Electron Theory of Solids," by Sir Joseph J. Thomson (page 281).

The President then recognized Doctor Modjeski, who read the paper on "Bridges—Old and New" (page 291).

CORRESPONDENCE.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY May 24, 1922.

SIR AUCKLAND GEDDES,
Ambassador Extraordinary and
Plenipotentiary of His Britannic Majesty,
British Embassy, Washington, D. C.

YOUR EXCELLENCY:

Again you have put The Franklin Institute under a pleasing obligation. While expressing the regret of our Management that you were not able to be here on the afternoon of Wednesday, May 17th, last, to receive on behalf of your government The Franklin Medal recently awarded to Sir Joseph J. Thomson, Master of Trinity College, Cambridge, England, in recognition of his scientific work, I am particularly requested to advise you of the pleasure felt that the Embassy was represented by its distinguished Secretary, Mr. R. L. Craigie. Knowing something of the splendid traditions of His Majesty's diplomatic service, it is believed that your selection of Mr. Craigie was a most happy inspiration. His remarks on receiving the medal for transmission to Sir Joseph were graceful, highly pleasing to all scientific people, sound and constructive, distinctly promoting friendships that must continuously obtain if civilization is to progress.

Once more expressing to you the Institute's sense of indebtedness, I am,

Your Excellency's Very Obedient Servant,

(Signed) R. B. OWENS,
Secretary.

RBO:H

BRITISH EMBASSY,
Washington,
May 27, 1922.

MY DEAR DR. OWENS,

I am very much obliged to you for your letter of the 24th instant, and I was glad to hear from you that Mr. Craigie's remarks on receiving the Medal, for transmission to Sir Joseph Thomson, met with the approval of the Institute.

I very much regret that, owing to other engagements, it was impossible for me to be present on the 17th instant.

I am, my dear Dr. Owens,

Very sincerely yours,

(Signed) A. GEDDES.

DR. R. B. OWENS,
Secretary, The Franklin Institute,
Philadelphia, Pa.

BRITISH EMBASSY,
WASHINGTON,
August 15, 1922.

MY DEAR DR. OWENS:

I have received a despatch from the Foreign Office informing me that the Earl of Balfour presented The Franklin Medal to Sir J. J. Thomson on the 26th of last month. The ceremony, which took place at the Department of Scientific and Industrial Research in the presence of the United States Ambassador, the President of the Royal Society and other distinguished men of science, was highly successful. Sir J. J. Thomson made an excellent speech largely devoted to Franklin as a man of science. A newspaper extract is enclosed herein which will give you some further details regarding the ceremony.

The Earl of Balfour wishes me to say that it gave him great pleasure to take part in conveying to Sir J. J. Thomson the honour conferred upon him by his fellow scientists in the United States.

Very sincerly yours,

(Signed) H. G. CHILTON.

DR. R. B. OWENS,
Secretary, The Franklin Institute,
Philadelphia, Pa.

HG: I.

(*The Times* (London), Thursday, July 27, 1922.)

SIR JOSEPH THOMSON HONOURED.

BROTHERHOOD OF SCIENCE.

SIR JOSEPH THOMSON, O.M., F.R.S., yesterday received The Franklin Gold Medal, presented to him by The Franklin Institute, Philadelphia, "for signal and eminent service in science." The presentation was made by Lord Balfour at the Department of Scientific and Industrial Research, Old Queen-street, Westminster, and the ceremony was attended by many of the leading figures in the scientific world on both sides of the Atlantic.

LORD BALFOUR said that in honouring Sir Joseph Thomson The Franklin Institute had not merely conveyed a signal sense of their estimate of Sir Joseph's merits as an individual, but they had conferred an honour upon the country where he was born and where he had done all the great work that had given him the distinguised place he occupied without contest among the scientific celebrities of the world. He (Lord Balfour) was sorry to say he was old enough to remember the giants who rendered physics illustrious in this country in the second half of the nineteenth century. He knew Lord Kelvin well; he knew others of his great Cambridge contemporaries; and their fame was not likely to be shaken by any discoveries which their successors might be fortunate enough to make. Yet he thought he would be borne out by all those competent to speak when he said that the last decade of the last century and successive years of the twentieth century would always be remembered

in the history of physical and mathematical science as some of the most fruitful and epoch making the world had ever known. (Cheers.)

Physical research had penetrated into regions never hitherto explored, and he well remembered that Lord Kelvin, who had himself done so much to prepare the new epoch, was nevertheless almost shocked by some of the theories which had now been accepted universally as representing the most recent advances in physical science. One of the greatest of pioneers in this greatest of scientific movements was Sir Joseph Thomson. (Cheers.) What he had done in physics, in electricity as a department of physics, in the structure of the atom, in all those investigations which were proving day by day more and more fruitful, which were opening up such astonishing and unimagined vistas into the truths of Nature, and the full importance of which only future generations would be able adequately to estimate—to all these great performances it would take far more time than they had at their disposal, and far more knowledge than he (Lord Balfour) pretended to possess, to do anyhing like justice.

SIR JOSEPH THOMSON said there was something besides a personal element in the bestowal of that honour—there was a contribution to the brotherhood of science between America and Britain. (Cheers.) He valued especially the association of the medal with the name of Franklin. He knew nothing quite analogous to Franklin's achievement in scientific history, for he obtained his immortal position practically by six years' work. He did it by sheer force of intellect, and he came to it without any scientific training. He had to the end of his life no mathematics. In fact, he was afraid Franklin classed mathematics and classics as things which it was quite undesirable to retain in a general scheme of education. (Laughter.) The writings of Franklin's contemporaries seemed out of date to-day, but not so Franklin's, and the striking thing about all his scientific work was that he appeared to regard it as a mere episode in his career to which he paid little importance. To find a man who had done work of the highest rank in so many subjects as Franklin, they had to go back to Leonardo da Vinci.

Among those present were:

Mr. H. Goold, representing the American Ambassador, Sir C. Sherrington (President), Sir David Prain (Treasurer), Mr. W. B. Hardy (Secretary), Sir Aubrey Strahan and Professor A. Harden, representing the Royal Society, Dr. Elwell Hendricks, representing the Society of Chemical Industries of New York and the American Chemical Society, Professor T. H. Goodspeed, Berkeley, U.S.A., Professor E. V. McCollum, Baltimore, U.S.A., Professor R. F. Ruttan, Canadian Advisory Council, and the following members of the Advisory Council of the Department of Scientific and Industrial Research: Sir William McCormick (Chairman), Professor J. B. Farmer, Sir George Beilby, Sir R. Threlfall, Professor S. Young, Sir J. F. C. Snell, Professor J. F. Thorpe, Sir H. Miers, and Sir H. Frank Heath (Secretary).

Milk Powders.—LEROY S. PALMER and C. D. DAHLE, of the University of Minnesota (*Jour. Dairy Science*, 1922, v, 240–245), have studied the structure of whole milk powders. Powders made by the spray process consist of spherical granules, each of which contains a spherical core of air. Powders manufactured by the drum process consist of irregular platelets free from cores of air. Spray process powders tend to deteriorate with the development of a strong tallowy odor; this deterioration is really an oxidation giving rise to rancidity. Drum process powders apparently do not undergo this deterioration. Palmer and Dahle suggest that the presence of the cores of air within the granules possibly has an important bearing on the deterioration of spray process powders. J. S. H.

Separation of Molybdenum from Tungsten.—DOROTHY HALL, of the Research Laboratory of the General Electrical Company (*Jour. Am. Chem. Soc.*, 1922, xliv, 1462–1465), recommends the following procedure for the quantitative separation of molybdenum from tungsten. Solid potassium xanthate is added to the neutral solution containing molybdenum and tungsten. Dilute (1:3) sulphuric acid is added drop by drop; the molybdenum is converted into its red xanthate; the tungsten is converted into soluble metatungstate, which may be reduced with the formation of a blue color. The solution is now shaken with chloroform, an immiscible solvent; the molybdenum xanthate passes into the chloroform layer, while the tungsten remains in the aqueous layer. This separation is most readily made when not more than 5 milligrams of molybdenum and not more than 1 gram of tungsten are present in the original solution.

J. S. H.

Manganese as an Industrial Poison.—GEORGE B. DAVIS and WALTER B. HUEY (*Jour. Ind. Hygiene*, 1921, iii, 231–238) report and describe two cases of chronic manganese poisoning. The men poisoned operated an electric furnace which was used for the melting of ferromanganese in a steel plant. J. S. H.

Industrial Carbon Monoxide Poisoning.—ALICE HAMILTON (*U. S. Bureau of Labor Statistics Bull. No. 291*, 47 pp., 1921) states that both acute and chronic carbon monoxide poisoning may occur in the industries. The acute poisoning may occur among workmen employed in the steel, illuminating gas, and coke industries, coal and metal miners, zinc smelters, garage men, and those working in plants using producer gas. The chronic poisoning may develop when workmen are exposed to an atmosphere in which carbon monoxide is more or less continuously present in low concentrations; this condition may exist in garages and about linotype machines. J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

MEASUREMENT OF THE COLOR TEMPERATURE OF THE MORE EFFICIENT ARTIFICIAL LIGHT SOURCES BY THE METHOD OF ROTATORY DISPERSION.[1]

By Irwin G. Priest.

[ABSTRACT.]

THIS paper describes and discusses a new method for measuring color temperatures between 3000° and 4000° absolute centigrade, and presents some data on the color temperature of the gas-filled tungsten lamp and the carbon arc.

The method is briefly this: Light from a source of known spectral distribution is modified by passage through a quartz plate between nicol prisms. The nicols and the quartz plate constitute in effect a blue filter of adjustable spectral transmission. The spectral transmission is adjusted by rotating one of the nicols. The source and the thickness of quartz are so chosen that the energy emerging from the second nicol has (for all positions to be considered) the spectral distribution characteristic of a complete radiator ("black body," Planckian formula). The light from the source whose color temperature is to be determined is color matched by rotating one of the nicol prisms. The temperature is obtained from this rotation by a method described in the paper.

The subject matter includes:

(1) A thorough discussion of the reliability of the standard source.

(2) Data upon the precision and accuracy of color temperature measurements at about 2850° K. It is shown that the probable error of a single observation is about ∓6°. Individual observers means (20 observations) differ from the mean of four observers by about 5°.

(3) Data upon the color temperature of the gas-filled tungsten lamp as a function of efficiency up to nearly the melting

* Communicated by the Director.

[1] Scientific Paper No. 443.

point of tungsten. The filament failed at a temperature of about 3644° K., the efficiency being about 39 lumens per watt.

(4) Data upon the color temperature of the crater of the carbon arc indicate a color temperature of about 3780° K. for solid carbons and 3420° K. for cored carbons.

PRACTICAL SPECTROGRAPHIC ANALYSIS.[3]

By W. F. Meggers, C. C. Kiess and F. J. Stimson.

[ABSTRACT.]

A BRIEF review of various methods which have been proposed for chemical analyses by means of the spectrum is followed by a detailed description of the principle, apparatus and procedure employed in making quantitative analyses from the spectra of condensed sparks. The principle is based on the well-known fact that if one examines the spectra of flames, arcs or sparks, either visually or photographically, it is seen that with the diminution of an element in a mixture its spectrum becomes simplified, more and more lines disappear, so that in general only one extremely sensitive line remains when a minute trace of the element is present. From a study of standard samples whose chemical composition is known, the partial spectrum of each element may be correlated with the amount present, thus furnishing a basis for estimating the composition of impure materials. Such tests have the widest application and are best controlled and interpreted when the materials are made luminous in a high potential capacity spark and the spectra of standard and unknown samples are photographed for comparison. The practical application of this method is illustrated by three examples taken from the work of the spectroscopy section of the Bureau of Standards. They deal with the quantitative determination of impurities in various samples of tin, gold and platinum. This spectrographic method of analysis is especially sensitive and useful in nearly all cases where small quantities of samples or impurities are to be tested and can therefore be used to advantage in supplementing assays or the wet methods of chemical analysis which in many such cases are difficult and uncertain. For routine work of this nature a standardized spectrographic method will furnish results of consider-

[3] Scientific Paper No. 444.

able accuracy and will reduce the time and expense involved by the more tedious methods. Other applications to problems in chemistry, metallurgy, mineralogy, physics, biology, etc., are suggested.

PHOTOMICROGRAPHY OF PAPER FIBRES.[1]

By R. E. Lofton.

[ABSTRACT.]

IT IS necessary that persons who intend taking up the subject of photomicrography make themselves thoroughly familiar with the laws and properties of light and lenses, the proper use of the microscope, and with the nature and properties of developers and the photographic plate.

It is not necessary, and is even a disadvantage, to have the illumination furnished by the carbon arc, which may be advantageously replaced by an incandescent lamp having a concentrated filament. The writer is using with entire success a 400-watt 110-volt Mazda stereopticon lamp, and has thus eliminated a cause of periodic diversion of attention from the object being studied and also a source of heat which frequently injures or destroys valuable equipment or delicate objects being photographed.

Achromatic objectives cannot be corrected for all wave-lengths of ordinary light, but are corrected for "apple green" light when intended for visual use, since the normal human eye is most sensitive to light of this color. But since all photographic plates are more sensitive to the blue-violet waves, objectives intended for photographic use are corrected for blue light. The color of light for which the objective is corrected is brought to a focus nearer the objective than are the other colors of the spectrum, so it follows that the visual focus and the photographic or chemical focus are not located at the same point. In the use of achromatic objectives, therefore, with ordinary light it is necessary for best results to use a light filter between the objective and source of light to "cut out" or absorb the colors of light not desirable. If the objective to be used is corrected for visual use, best results will usually be obtained if a filter is used which transmits only the

[1] Technologic Papers, No. 217.

yellow-green; but if the objective is corrected for photographic use, the filter used with it should transmit only blue light.

Apochromatic objectives, however, are corrected for all the components of white light, and thus bring to the same focus both the visual and the chemical rays, so that it is not necessary to filter the light when using them with compensating oculars. But if one wishes to use an apochromatic objective without a compensating ocular it will be necessary to use monochromatic light, as this objective is so constructed that it will not give an image free from color, if ordinary light is used, except in combination with a compensating ocular.

Three types of filters are in common use: (1) Liquid filters (dyes in solution), (2) those made of colored glass, and (3) stained or dyed transparent films. Liquid filters do not usually keep well and are apt to be spilled and do damage. Those in the other two classes are in general much more satisfactory. A very satisfactory filter can often be made in the workroom by removing the silver salts from a photographic plate and staining the clear gelatin film in a dye bath. Filters may be examined quickly for the quality of light they transmit by means of a grating or a replica.

In using objectives of 8 mm. or greater equivalent focus a regular substage condenser is not desirable, as better results can usually be obtained with a condenser arrangement which sends a narrow parallel beam of light into the objective.

A substage diaphragm should be used, especially if a condenser of high numerical aperture is being used. A very small diaphragm should not be used in any case, as diffraction effects with consequent loss of resolution are sure to result.

If the object to be photographed lies in slightly separated planes vertical to the axis of the optical system, an objective of longer focal length, since it has greater "penetrating power," will give better results than one of shorter focal length. An objective of greater focal length also gives a larger and a flatter image. At the same time a longer bellows extension must be used by which means the image to be recorded on the photographic plate will be as free as possible from curvature and will show most detail in the object.

The proper plate to use will depend on the color and the other properties of the material to be photographed; but whether an

ordinary, orthochromatic, or panchromatic plate is to be used, best results can be had only by the use of a fairly slow plate. Development should be carried out with a strong solution, so that plenty of contrast will appear in the finished negative.

It is very important that the microscopist be familiar with the characteristics of the fibres to be photographed, and that a field be selected for photographing which will show the distinguishing properties and the correct proportion of all the fibres or cells composing the sample.

The use of stains and dyes has the advantage of aiding in identifying various fibres by bringing to view characteristic markings and by having different staining effects on different fibres and on different elements of the same fibre. By slight staining of the fibres the gray background so often seen in reproductions of photomicrographs may be eliminated.

Photomicrography affords a rapid, inexpensive, and accurate means for preparing permanent records in the study of the quality, adulteration, or deterioration of raw materials and in the control of various mill processes.

CONSTRUCTION AND OPERATION OF A TWO-CIRCUIT RADIO RECEIVING EQUIPMENT WITH WITH CRYSTAL DETECTOR.[4]

[ABSTRACT.]

THE apparatus used for the reception of radio messages may be a homemade affair, very simple and inexpensive, or it may be elaborate and expensive. All that is necessary for receiving radio messages is a device for collecting power from incoming radio waves, a suitable circuit adjusted or "tuned" electrically to the frequency of the incoming waves, and apparatus for changing the received power into audible sounds.

Bureau of Standards Circular No. 120, "The Construction and Operation of a Simple Homemade Radio Receiving Outfit," described the method of constructing in the home a very simple and inexpensive single-circuit crystal detector receiving set from materials which can be easily secured. Circular No. 120 was the first of a series of circulars describing the construction of homemade radio receiving sets. The publication of these circulars

[4] Circular No. 121.

was undertaken by the Bureau of Standards at the request of the States Relation Service of the United States Department of Agriculture acting in coöperation with the Bureau of Markets and Crop Estimates of the same Department.

The Circular here described is the second of this series, and gives directions for the construction of a more elaborate receiving set, having two circuits instead of a single circuit. This set has a variable condenser, and a coupling coil by means of which variable coupling may be secured. With this set more selective reception may be obtained, that is, stations which it is not desired to receive can be tuned out, and stations which it is desired to hear can be heard better. The set has more adjustments than the one described in Circular No. 120.

In the construction of the two-circuit receiving outfit, the antenna, lightning switch and ground connections described in Bureau of Standards Circular No. 120 can be used. The receiving set itself consists of two separately tuned circuits, a crystal detector, and telephone receivers. The total cost of the complete equipment will vary from about $15.00 to $24.00. If one has constructed the equipment described in Circular No. 120, the cost of additional parts required to construct the equipment described in this Circular will be from $3.00 to $8.00.

The complete receiving station is divided into the following parts: (1) Antenna, (2) lightning switch, (3) ground connections, (4) receiving set, and (5) telephone receivers. The receiving set may be subdivided into (1) the coupler (with its variable tuning condenser) and (2) the crystal detector.

The "means of absorbing the energy from the waves" is the antenna, the "means of tuning" consist of the coupler and variable condenser, and the "means of making audible the high-frequency radio currents" consist of the detector and telephone receivers.

The antenna may be a wire 75 feet long between insulators which are attached to buildings or other convenient supports.

The lightning switch is a single-pole double-throw porcelain base switch, and is so connected that the antenna may be grounded when not in use.

The coupler has a "primary" and a "secondary" coil. The primary coil is made a part of the electrical circuit between the antenna and ground. The coil is made by winding insulated wire

on cardboard tubing and the desired number of turns is controlled by switches which tune the primary circuit to the desired wave frequency. The secondary coil is similar to the primary coil except that the number of turns is controlled by a single switch. This coil, which is slightly smaller in diameter than the primary, is arranged so that it may be pushed into the latter, and the terminals of the coil are connected to a variable condenser so that the complete secondary circuit may be tuned to the frequency of the primary circuit. When this occurs there is a transfer of energy between the two circuits, and the signals are made audible by a crystal detector and telephone receivers. The detector is made by mounting a tested piece of the mineral galena so that it is in contact with a fine wire. The telephone receivers must be purchased, and although a single telephone receiver may be used, it is more desirable to use two telephone receivers having a combined resistance of 2000 ohms or more.

The equipment described in this Circular will receive music and voice from high-power radio telephone transmitting stations from a distance of about 75 miles, and will receive stations of lower power over a distance of about ten miles. Much greater distances may sometimes be covered at night.

THE SPECTRAL TRANSMISSIVE PROPERTIES OF DYES.

By K. S. Gibson, H. J. McNicholas, W. E. Mathewson, E. P. T. Tyndall, and M. K. Frehafer.

[ABSTRACT.]

I. Of Seven Permitted Food Dyes in the Visible, Ultra-violet, and Near Infra-red.[5]

THE paper presents the beginning of an extended investigation of the spectral transmissive properties of dyes. The purpose of this first paper is (1) to outline the scope of the work, (2) to describe the apparatus and methods used, and (3) to present the data already obtained.

Owing to the arbitrary conventions in nomenclature, symbols, and units heretofore employed, it has seemed advisable to formulate a complete system of nomenclature for the subject, part of which is presented in this paper. In this system, *Transmittancy* is defined as the ratio of that fraction of the incident

[5] Scientific Papers, No. 440.

radiant energy which is transmitted by a cell containing the solution, to that fraction of incident energy of the same intensity which is transmitted by the same or a duplicate cell containing the solvent. It is the quantity obtained directly from the observations. *Specific Transmissive Index* equals $-Log_{10}$ *Transmittancy* for unit concentration and thickness. The units employed are 1 cg. per litre and 1 cm. respectively.

The experimental data are presented in the form of graphs and tables. The *graph* forms are of two kinds: (1) with $-Log_{10}$ *Transmittancy* from 0.00 to 2.00 as ordinates and *Wave-length* in millimicrons from 390 to 770 as abscissæ; (2) with ordinates the same as above and having as abscissæ the *Frequency* in vibrations per 10^{-12} seconds from 300 to 1300. The *tables* give the specific transmissive index for homogeneous light of various wave-lengths, from mercury and helium lamps, throughout the visible spectrum, and the values of index and frequency (and wave-length) of the maxima and minima of the absorption bands throughout the whole range.

Four methods were used to obtain the experimental data:

(1) *Visual Method.*—The König-Martens polarization spectrophotometer was used. (*Ann. der Phys.* (4) **12**, p. 985, 1903.) Auxiliary apparatus for illuminating the spectrophotometer field is partially described in B. S. Technical Papers, No. 148. This method was used in the range of wave-lengths 436 to 710 millimicrons.

(2) *Photographic Method.*—The Hilger sector photometer with a quartz spectrograph was used over the wave-length range of 240 to 500 millimicrons. The source of radiant energy was a high-voltage (Tesla coil) spark under water, which gives a continuous spectrum throughout the visible and ultra-violet as far as the quartz system will transmit.

(3) *Photoelectric Null Method.*—This method and apparatus are fully described in B. S. Sci. Papers No. 349. A Hilger constant-deviation spectrometer with glass prism and lenses was used. Because of the absorption by the glass in the ultra-violet, and of the long wave-length limit of sensitivity of the potassium-hydride photoelectric cells, the range of practical use of this method was limited to 380 to 600 millimicrons. It has its

maximum sensitivity, however, in the blue where the visual and photographic methods are relatively weak.

(4) *The Thermoelectric Method.*—The calibration of the drum of the Hilger constant-deviation spectrometer was extended into the near infra-red, enabling the instrument to be used throughout the range in which 1 cm. of water has any appreciable transmission. The radiometric apparatus consisted of a thermopile and galvanometer, and the usual deflection method was used. The approximate wave-length range of the method was 600 to 1360 millimicrons.

The absorption cells were so constructed that the solution came in contact with glass or quartz only, and were kept at a constant temperature by means of a water bath regulated by a thermostat.

The data as actually obtained by the different methods are plotted on the graph forms, and as the wave-length ranges of the different methods overlap to a considerable extent, these graphs afford a means of thoroughly studying the accuracy of measurement attainable with these various instruments and methods. Systematic errors have in this way been studied and, as far as possible, eliminated, so that very good agreement between methods is attained.

The dyes investigated were seven of the permitted food dyes—Naphthol-Yellow S, Orange I, Ponceau 3R, Amaranth, Erythrosine, Indigo Disulpho Acid, and Light Green SF Yellowish. It was desired to obtain the data on these substances in pure water solution. They all, however, show the properties of indicators, and as ordinary distilled water may show considerable variation in its H-ion concentration, a sufficient quantity of a salt-mixture regulator was added to fix the acidity of the solvent within somewhat narrower limits. Erythrosine, however, was dissolved in pure distilled water.

Concentrations of 1, 10, 100, and 1000 centigrams per litre, thicknesses of 1, 2, 4, and 10 centimetres, and temperatures of 25 and 40° C., were used. Deviations from Beer's law were noted; and also temperature effects.

An inspection of the graphs and tables must be made by those interested, inasmuch as this kind of data is not readily summarized.

WAVE-LENGTH MEASUREMENTS IN THE ARC SPECTRA OF NEODYMIUM AND SAMARIUM.[6]

By C. C. Kiess.

[ABSTRACT.]

THE arc spectra of neodymium and samarium were photographed with a large concave grating spectrograph, the photographic plates being suitably sensitized to record the spectra from the green to the infra-red. About 1500 lines were measured in each spectrum, most of them being of low intensity. No bands were observed in either spectrum, although a few unsymmetrical lines may be regarded as band heads. About 125 lines common to both spectra have been segregated into a separate table. These lines may be characteristic of the element of atomic number 61 which comes between neodymium and samarium, but which has not yet been isolated. The materials used for the work were neodymium oxalate and samarium oxide prepared at the University of Illinois and samarium oxalate prepared at New Hampshire College. This work is a continuation of a study of the spectra of the rare earth elements of which a first report is given in B. S. Scientific Papers, No. 421.

UNITED STATES GOVERNMENT SPECIFICATION FOR WHITE FLOATING SOAP.[7]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a high-grade cake soap, at least as good in every respect as one made from soda and a mixture of high-grade tallow with 25 to 30 per cent. of coconut

[6] Scientific Papers, No. 442.

[7] Circular No. 123.

oil; of good light color; thoroughly saponified; so prepared as to float on water. Bidder shall state size, weight and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 34 per cent. Deliveries which yield more than 34 per cent. volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol and sodium chloride shall not exceed 2.0 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.15 per cent.

Chloride, calculated as sodium chloride (NaCl), shall not exceed 1 per cent.

Matter insoluble in water shall not exceed 0.2 per cent.

Rosin, sugar and foreign matter shall not be present.

The acid number of the mixed fatty acids prepared from the soap must be not less than 212.

Odor and character of cake must be as specified by the purchaser.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received but all other constituents will be calculated on the basis of material containing 28 per cent. of volatile matter.

The material will be purchased by net weight, provided the matter volatile at 105° C. does not exceed 28 per cent. With deliveries containing more than 28 per cent. but not exceeding 34 per cent. of matter volatile at 105° C., settlement will be made on the basis of 28 per cent. of matter volatile at 105° C., *i.e.*, seventy-two one-hundredths (72-100) of a pound of non-volatile matter shall be considered one (1) pound of soap.

UNITED STATES GOVERNMENT SPECIFICATION FOR LIQUID SOAP.[8]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal

[8] Circular No. 124.

Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a clear solution of pure vegetable oil potash (or potash and soda) soap with or without glycerol or alcohol, suitably perfumed and free from all foreign matter. It should quickly form a satisfactory lather and have no injurious effect, and leave no objectionable odor on the skin.

Bidder shall state number of gallons to the container.

Failure to meet any of the following requirements will be cause for rejection:

The material must be a clear solution, free from objectionable odor, other than from coconut oil, and must quickly form a satisfactory lather.

Total anhydrous soap shall be not less than the equivalent of 15 per cent. potash soap.

Total matter insoluble in alcohol shall not exceed 0.5 per cent.

Free alkali calculated as potassium hydroxide (KOH) shall not exceed 0.05 per cent.

Chloride calculated as potassium chloride (KCl) shall not exceed 0.3 per cent.

More than traces of sulphates and sugar shall not be present.

All constituents shall be calculated on the basis of the original sample.

The material will be purchased by volume in accordance with the contract agreement. A gallon of soap shall mean 231 cubic inches at 15.5° C.

UNITED STATES GOVERNMENT SPECIFICATION FOR SOAP POWDER.[1]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty

[1] Circular No. 125.

Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The material desired under this specification is a uniform mixture of soap and sodium carbonate in powdered form; it should be readily soluble in tepid water and should contain no free caustic alkali or inert fillers.

Bidder shall state size and number of pounds to the package.

Failure to meet any of the following requirements will be cause for rejection:

Anhydrous soap shall be not less than 15 per cent.

Sodium carbonate (Na_2CO_3) shall be not less than 30 per cent. (The aggregate of anhydrous soap and sodium carbonate shall be not less than 55 per cent.)

Material will be purchased by net weight.

UNITED STATES GOVERNMENT SPECIFICATION FOR SALT WATER SOAP.[10]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a soap well made from pure coconut oil and the necessary alkali. It must be entirely soluble in both sea water and fresh water, and make a suitable

[10] Circular No. 126.

lather. Bidder shall state size, weight and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 55 per cent.

Deliveries which yield more than 55 per cent. of volatile matter will be rejected without further test.

Total matter insoluble in alcohol shall be not less than 2 per cent. nor more than 3 per cent., and shall consist essentially of sodium carbonate (Na_2CO_3).

Free alkali, calculated as sodium hydroxide (NaOH) shall not exceed 0.5 per cent.

Matter insoluble in water shall not exceed 0.5 per cent.

Chloride, calculated as sodium chloride (NaCl), shall be not less than 2.5 per cent. nor more than 3.5 per cent.

Rosin, sugar and foreign matter shall not be present.

The acid number of the mixed fatty acids prepared from the soap shall be not less than 250.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 55 per cent. of volatile matter. The material will be purchased by net weight.

UNITED STATES GOVERNMENT SPECIFICATION FOR AUTOMOBILE SOAP.[11]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a pure vegetable-oil paste soap, containing no free alkali or acid; relatively free

[11] Circular No. 127.

from matter insoluble in alcohol; homogeneous; free from adulterants of any kind and without objectionable odor. Bidder to state size and weight of unit.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 55 per cent. Deliveries which yield more than 55 per cent. of volatile matter will be rejected without further test.

The sum of free alkali and total matter insoluble in alcohol shall not exceed 1.0 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.2 per cent.

Free acid, calculated as oleic, shall not exceed 0.2 per cent.

Matter insoluble in water shall not exceed 0.2 per cent.

Unsaponified matter shall not exceed 4.0 per cent.

Rosin shall not be present.

Odor must be as specified in contract.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 50 per cent. of volatile matter.

The material will be purchased by net weight.

UNITED STATES GOVERNMENT SPECIFICATION FOR CHIP SOAP.[11]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a soap in chip form, made from soda and fats, without rosin, as free as possible from water and all substances other than true soap, of a light

[11] Circular No. 128.

uniform color, free from disagreeable odor, and suitable for high-grade laundry work with soft water, when the presence of alkaline salts is objectionable.

Bidder shall state size and weight of package.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 15 per cent. Deliveries which yield more than 15 per cent. of volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol and sodium chloride shall not exceed 3.0 per cent.

Free alkali, calculated as sodium hydroxide (NaOH) shall not exceed 0.5 per cent.

Matter insoluble in water shall not exceed 0.2 per cent.

Titer of the mixed fatty acids prepared from the soap must be not less than 39° C.

Color and odor must be as specified.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 10 per cent. of volatile matter.

The material will be purchased by net weight, provided the matter volatile at 105° C. does not exceed 10 per cent. With deliveries containing more than 10 per cent., but not exceeding 15 per cent. of matter volatile at 105° C., settlement will be made on the basis of 10 per cent. of matter volatile at 105° C., *i.e.*, nine-tenths (9-10) of a pound of non-volatile matter will be considered one (1) pound of soap.

UNITED STATES GOVERNMENT SPECIFICATION FOR ORDINARY LAUNDRY SOAP.[13]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were pre-

[13] Circular No. 129.

pared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a well made, uniformly mixed laundry or common soap, made from soda and fats, with no excessive proportion of rosin and a moderate amount of matter insoluble in alcohol; free from objectionable odor or makeweights; suitable for use with moderately hard water for general cleaning and laundry purposes.

Bidder shall state size, weight and number of cakes in each box.

Failure to meet the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 36 per cent. Deliveries which yield more than 36 per cent. volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol and sodium chloride shall be not less than 2 per cent. nor more than 10 per cent.

Free alkali calculated as sodium hydroxide (NaOH) shall not exceed 0.5 per cent.

Matter insoluble in water shall not exceed 1.0 per cent.

Rosin shall not exceed 25 per cent.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 34 per cent. of volatile matter.

The material will be purchased by net weight provided the matter volatile at 105° C. does not exceed 34 per cent. With deliveries containing more than 34 per cent. but not exceeding 36 per cent. of matter volatile at 105° C., settlement will be made on the basis of 34 per cent. of matter volatile at 105° C., *i.e.*, sixty-six one-hundredths (66-100) of a pound of non-volatile matter shall be considered one (1) pound of soap.

UNITED STATES GOVERNMENT SPECIFICATION FOR GRIT CAKE SOAP.[14]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap

[14] Circular No. 130.

Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

(*a*) *Grit Cake Soap, for Fine Work, Such as Glass and Enamel.*—The material desired under this specification is a compact cake soap containing about nine-tenths of its weight of clean, finely divided, siliceous material, which will not scratch glass or enameled surfaces, unscented and of a light gray or white color. Cakes to be well compressed and of a satisfactory degree of friability which must not be materially affected or lessened after immersion in, or contact with, water. Bidder shall state size, weight and number of cakes to each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 4 per cent. Deliveries which yield more than 4 per cent. of volatile matter shall be rejected without further test.

Alkali is alkaline salts (total alkalinity of matter insoluble in alcohol) calculated as sodium carbonate (Na_2CO_3) shall not exceed 1.0 per cent.

Free alkali calculated as sodium hydroxide (NaOH) shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 88 per cent. nor more than 93 per cent. This insoluble siliceous material must be mainly ground feldspar and all must pass a No. 100 screen and at least 95 per cent. must pass a No. 200 screen.

Rosin, sugar and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent. of the difference between 100 and the sum of the matter volatile at 105° C. insoluble siliceous material and alkali as alkaline salts.

Material will be purchased by net weight.

(*b*) *Grit Cake Soap; For Scouring and Scrubbing.*—The material desired under this specification is a compact cake soap containing about four-fifths of its weight of clean, finely divided,

siliceous material; unscented and of a light gray or white color. Cakes to be well compressed and of a satisfactory degree of friability which must not be materially affected or lessened after immersion in, or contact with, water. Bidder shall state size, weight and number of cakes to the box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 5 per cent. Deliveries which yield more than 5 per cent. of volatile matter shall be rejected without further test.

Alkali as alkaline salts (total alkalinity of matter insoluble in alcohol) calculated as sodium carbonate (Na_2CO_3) shall not exceed 3 per cent.

Free alkali calculated as sodium hydroxide (NaOH) shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 75 per cent. nor more than 85 per cent. This insoluble siliceous material should be mainly quartz. It all must pass a No. 100 screen.

Rosin, sugar and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent. of the difference between 100 and the sum of the matter volatile at 105° C., insoluble siliceous material and alkali as alkaline salts.

Material will be purchased by net weight.

UNITED STATES GOVERNMENT SPECIFICATION FOR SCOURING COMPOUNDS, FOR FLOORS, (*a*) AND (*b*) AND SOAP SCOURING COMPOUND (*c*).[15]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in

[15] Circular No. 131.

coöperation with the two committees mentioned above. The general requirements are:

(*a*) *Scouring Compound for Fine Marble Floors.*—The material desired under this specification is a uniform powder containing about nine-tenths of its weight of clean, finely divided, siliceous material, the remainder being sodium carbonate, or soap or both. It must not scratch nor discolor the surfaces on which it is to be used; to be unscented and of a light gray or white color. Bidder shall state size and weight of package.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 10 per cent.

The sum of sodium carbonate and anhydrous soap shall not exceed 7 per cent. nor be less than 2 per cent.

Free alkali calculated as sodium hydroxide (NaOH) shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 85 per cent. nor more than 95 per cent. It all must pass a No. 100 screen and at least 95 per cent. must pass a No. 200 screen; it must not scratch marble.

Material will be purchased by net weight.

(*b*) *Scouring Compound for Tile or Ceramic and Terrazzo Floors.*—The material desired under this specification is a uniform powder containing about nine-tenths of its weight of clean, finely divided siliceous material, the remainder being sodium carbonate or soap, or both; to be unscented and of a light gray or white color. Bidder shall state size and weight of package.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 10 per cent.

The sum of sodium carbonate (Na_2CO_3) and anhydrous soap shall not exceed 10 per cent. nor be less than 2 per cent.

Insoluble siliceous material shall be not less than 85 per cent. nor more than 95 per cent. Ninety per cent. must pass a No. 80 screen and at least 99 per cent. must pass a No. 60 screen.

Free alkali calculated as sodium hydroxide (NaOH) shall not exceed 0.1 per cent.

Material will be purchased by net weight.

(*c*) *Soap Scouring Compound.*—The material desired under this specification is a mixture of finely powdered, light colored

siliceous material, sodium carbonate, and powdered soap; it must be free from caustic alkali and be unscented. Bidder shall state size and weight of package.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 10 per cent.

Carbonated alkali calculated as sodium carbonate (Na_2CO_3) shall be not less than 15 per cent. nor more than 20 per cent.

Free alkali calculated as sodium hydroxide (NaOH) shall not exceed 0.1 per cent.

Anhydrous soap shall be not less than 5 per cent. nor more than 10 per cent.

Insoluble siliceous material shall be not less than 60 per cent. nor more than 80 per cent. Ninety per cent. must pass a No. 80 screen and at least 99 per cent. shall pass a No. 60 screen.

UNITED STATES GOVERNMENT SPECIFICATION FOR HAND GRIT SOAP.[18]

[ABSTRACT.]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the Soap Committee of the Soap Section of the American Specialty Manufacturers' Association, and was promulgated by the Federal Specifications Board on June 20, 1922. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The material desired under this specification is a high-grade cake soap containing about one-third its weight of clean, finely divided, insoluble, siliceous matter; as free as possible from water; either uncolored or colored in a manner indicated in the contract; either unscented or perfumed in a manner indicated in the contract of the same; thoroughly saponified; well compressed in firm, smooth cakes.

Bidder shall state size, weight and number of cakes in each box.

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[18] Circular No. 132.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 25 per cent. Deliveries which yield more than 25 per cent. of volatile matter will be rejected without further test.

Alkali as alkaline salts (total alkalinity of matter insoluble in alcohol) calculated as sodium carbonate (Na_2CO_3) shall not exceed 1.0 per cent.

Free alkali calculated as sodium hydroxide (NaOH) shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 25 nor more than 40 per cent. This siliceous material must be so finely ground that not less than 98 per cent. of it will pass through a No. 100 screen and not less than 90 per cent. of it will pass through a No. 200 screen.

Rosin, sugar and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent. of the difference between 100 and the sum of matter volatile at 105° C., insoluble siliceous material and alkali as alkaline salts.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated to the basis of material containing 25 per cent. of matter volatile at 105° C.

Material will be purchased by net weight.

Qualitative Test for Uranium.—HAROLD D. BUELL, of Syracuse University (*Jour. Ind. Eng. Chem.*, 1922, xiv, 593), has devised the following qualitative test for uranium. A solution of the sample in nitric acid is prepared. An excess of granulated zinc is added, and the reaction is permitted to continue until the acid is spent. If the reaction occur too slowly, more nitric acid is added; if too violently, the solution is diluted with water. A yellow deposit forms on the excess (undissolved) zinc if uranium be present. This deposit apparently has the formula $UO_2.2H_2O$. This test may not be applied in the presence of sulphuric acid or hydrochloric acid. Gold, platinum, tungsten, lead, mercury, copper, titanium, chromium, and thorium do not interfere with the test. Iron and vanadium interfere only when present in large amounts; in such a case, the spent liquid is removed; the excess zinc and the precipitate are treated with sufficient nitric acid to start a reaction; the precipitate dissolves; and the yellow deposit appears as the acid is exhausted. This test is sufficiently sensitive to show the presence of 0.88 millegram of uranium in 1 cubic centimetre of solution. J. S. H.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

ELECTROCHEMICAL ASPECTS OF PHOTOGRAPHIC DEVELOPMENT.[1]

By S. E. Sheppard.

[ABSTRACT.]

THE early part of this paper discusses the history of the theory of development as a reversible chemical reaction. The conception of reduction potentials is considered, and it is pointed out that two different methods of presentation have been evolved. According to one reduction potential depends on the transfer of electric charges while according to the other it depends on the decomposition of water and release of atomic hydrogen. It is shown that under certain conditions these two conceptions are equivalent to each other in determining true reduction potentials. The principle condition is the presence in equilibrium of the reduction and oxidation products of the reaction. The work of F. C. Frary and A. H. Nietz is considered in this connection. Before satisfactory reduction potentials for organic developing reagents can be determined the following data must be secured:

A. Determination of the state in solution of the reducing agents;

B. Nature, and to some extent, the velocities of the reaction;

C. Silver equivalent of the reducer during the working period of development.

As contributory to these points the ionization constants of paraminophenol, elon, hydroquinone, and pyrogallol have been determined from the electrometric titration curves.

THE REMOVAL OF FREE ACID FROM NITROCELLULOSE WITH SPECIAL REFERENCE TO THE USE OF SALINE LEACHES.[2]

By S. E. Sheppard.

[ABSTRACT.]

THIS paper contains an account of the physical chemistry of the removal of acid from nitrocotton. Evidence is brought

* Communicated by the Director.

[1] Communication No. 121 from the Research Laboratory of the Eastman Kodak Company and published in *Trans. Amer. Electrochem. Soc.*, 1921, p. 29.

[2] Communication No. 128 from the Research Laboratory of the Eastman Kodak Company and published in *J. Ind. Eng. Chem.*, 699, 1921.

forward that the last traces in the order of 1 per cent. of acid retained by nitrocellulose is not held mechanically but adsorbed, the evidence in favor of this being mainly the effect of heat and of saline leaches, respectively, in accelerating the removal of the acid and changing the course of the curve expressing the rate of removal. The use of concentrated saline leaches, notably that of sodium sulphate, is discussed in detail and its application to the purification of nitrocellulose. From special experiments on the combination of pulping with other treatment it is concluded that the effect of pulping is mainly valuable on a large scale in procuring uniformity and of little direct effect on the fibres. From experiments on partial reprecipitation of nitrocellulose from acetone solutions and centrifugal fractionation, it is considered "stabilizing treatments" are less concerned with the chemical destruction of cellulose sulfuric esters and of lower nitrates of cellulose than with peptization and removal of cellulose dextrin derivatives.

THE ACTION OF SOLUBLE IODIDES AND CYANIDES ON THE PHOTOGRAPHIC EMULSION.[1]

By S. E. Sheppard.

[ABSTRACT.]

A RE-EXAMINATION of the fogging action of iodides on photographic emulsions discussed by Sheppard and Meyer in the *Photographic Journal* (60, 12, 1920) has been made. In a subsequent paper Mr. F. F. Renwick reported the discovery of a red sensitizing action of soluble iodides and cyanides on the emulsion, and attributed the fogging action observed by Sheppard and Meyer to such a sensitizing effect. In the present paper it is shown that with the emulsions used by Sheppard and Meyer bathing with potassium iodide produces practically no red sensitizing, but that this is effected with the emulsions used by Renwick. An investigation of a large number of commercial emulsions showed the effect to be specific to certain emulsions. In discussing the mechanism of such red sensitizing by iodides and cyanides evidence is brought forward contrary to Renwick's hypothesis and favoring a photocatalytic explanation; it is suggested that the orienting effect of the iodine ion of the silver halide crystal lattice modifies the aggregation of colloid silver produced by light of short wave-lengths so that sensitizing for longer wave-lengths is effected.

[1] Communication No. 130 from the Research Laboratory of the Eastman Kodak Company and published in *Photo. J.*, **88**, 1922.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

A STUDY OF METHODS OF MINIMIZING SHRINKAGE IN SHELL EGGS DURING STORAGE.[1]

By L. H. Almy, H. I. Macomber, and J. S. Hepburn.

[ABSTRACT.]

IMMERSION of eggs for short periods in heated or unheated solutions of mineral or organic acids, mineral salts, or soap in water were of but slight value in reducing shrinkage in eggs held at room or higher temperature. The loss in weight of eggs treated with heated cotton-seed oil was 6.3 per cent. and that of those treated with a heated mineral oil (specific gravity 0.869, flash point 350° F., viscosity at 100° F. 134 units, Saybolt) was 7.4 per cent. of that of untreated eggs. Lighter mineral oils, two other vegetable oils, and an animal oil were less satisfactory. Addition of gums, waxes, or rosin failed to increase the efficiency of the better mineral oil. The presence of 1 or 2 per cent. of soap markedly increased the sealing value of the more inferior mineral oils.

THE ROLE OF CYSTINE IN THE DIETARY PROPERTIES OF THE PROTEINS OF THE COW-PEA, VIGNA SINENSIS, AND OF THE FIELD PEA, PISUM SATIVUM.[2]

By A. J. Finks, Carl O. Johns, and D. Breese Jones.

[ABSTRACT.]

THE proteins of the cow-pea, *Vigna sinensis*, like those of the *Phaseolus* beans, are limited in their nutritive value by a deficiency of cystine and by an indigestibility which can be remedied by cooking. Only one-third to two-thirds of the normal rate of growth of albino rats was obtained on a diet in which 70 per cent. of cow-pea meal, equivalent to 16.5 per cent. of protein, furnished the sole source of protein.

Field-pea (*Pisum sativum*) meal, fed at the same protein level,

* Communicated by the Chief of the Bureau.

[1] Published in *J. Ind. Eng. Chem.*, **14** (1922) : 525.

[2] Published in *J. Biol. Chem.*, **52** (1922) : 403.

enabled rats to grow at a practically normal rate without the addition of cystine and without cooking.

The proteins of the field pea and those of the cooked cow-pea plus cystine were equally efficient in promoting growth at a practically normal rate, while the proteins of the cow-pea, raw plus cystine, or cooked without cystine, were less than half as well utilized as those of the field pea.

SAUERKRAUT AND ITS PRODUCTION.[3]

By Edwin LeFevre.

[ABSTRACT.]

CABBAGE is properly cured by the acid brine formed by the action of a group of lactic bacteria always present on cabbage. The presence of yeasts is not essential to this fermentation. A temperature of approximately 86° F. is required to secure the maximum activity of the fermenting organisms. If properly fermented under sanitary conditions sauerkraut, fermented salt cabbage, is a pure and wholesome product. The best way to market it is in the canned form.

WOOL SCOURING WASTES FOR FERTILIZER PURPOSES.[4]

By F. P. Veitch.

[ABSTRACT.]

MORE than 600,000,000 pounds of wool are scoured in this country annually. On the average, the grease content of this wool is approximately 14 per cent. and the potash (K_2O) content is about 4 per cent., while nitrogenous constituents other than those of the wool itself fall below 1 per cent., on the basis of the unscoured wool. The possibility of utilizing the potash and nitrogenous constituents for fertilizer purposes is being studied in the Bureau of Chemistry. Experiments on the manufacturing scale have shown that the material can be handled satisfactorily in the factory. The problem which remains to be solved is, whether or not these materials can be recovered and used economically.

[3] Published in *Canner*, Vol. 55, No. 2, Serial No. 1432, p. 27.

[4] Published in *J. Ind. Eng. Chem.*, **14** (1922) : 434.

NOTES FROM THE U. S. BUREAU OF MINES.*

APPLICATION OF THE GEOPHONE TO MINING.

By Alan Leighton.

THE geophone, which was invented by the French during the World War to detect underground mining operations, was developed by the United States Engineers, and the instruments now used by the Bureau of Mines were made according to plans drawn by the Engineers, except for the introduction of different diaphragms.

By the use of two geophones, one instrument to each ear, it is possible to determine the direction from which a sound is coming through the earth. A perpendicular, erected halfway between the instruments, according to principles worked out by the Bureau's investigators, will give the direction of the source of sound, or, more accurately, the projection of this line of direction on the horizontal plane will pass through the source of sound.

For use in determining the best ways of operating the geophone for rescue work in mine accidents, and for mine surveying, data must show two things: (1) The proper place to locate the geophone, and (2) the proper place to pound, in order that sounds may be detected and their point of origin determined. Rails and pipe lines can not be relied on to transmit the sounds from blows of different sorts, unless these lines are properly suspended throughout their length. Clay veins or faults interfere greatly with attempts to ascertain the direction from which the sound is coming.

Observations made over the Bureau's experimental mine through the greatest depth of cover—138 feet—show that pounding on the rib with either a timber or a sledge can be perceived on the surface anywhere within a circle whose diameter is 700 to 800 feet, the pounding being located at the centre of this circle. The experiments showed that a blow struck in a mine, with the purpose of being detected by the geophone, should be struck upon the coal. To detect sounds coming through the strata, the instrument should be placed on a niche or shelf of coal rather than on

* Communicated by the Director.

the floor of the mine. An entombed miner should keep up a continuous, though not rapid, pounding, if geophones are used in rescue work at that mine.

Geophones supply a quick and fairly accurate method of mine surveying. They can be used to advantage in guiding tunnels together, in preventing accidents at blasting through, and in locating mine fires, bore holes, faults, and "clay veins." The complete report on the geophone with illustrations has just appeared as Bureau of Mines Technical Paper No. 277.

COMMINUTED SMOKELESS POWDER FOR BLASTING.

By C. E. Munroe and Spencer P. Howell.

THE Bureau of Mines has issued a fourth report of a series of investigations made to ascertain how military explosives can be most efficiently and safely used for industrial blasting. This report describes the physical and chemical properties of comminuted (finely ground) smokeless powder, gives precautions for handling and packing it, and for preparing cartridges and boreholes in its use, presents in detail the results of field tests in blasting stumps, boulders, and ditches, and compares these results with those obtained from dynamite and other explosives.

As the gaseous products of detonation include poisonous and inflammable carbon monoxide, comminuted smokeless powder is unsuitable for use as an explosive in dusty and gaseous coal mines or in other places where inflammable dust, gases, or vapors may be encountered. Nor should it be used in mines, tunnels, or other close places, unless the ventilation is very good and workmen are not in contact with the poisonous gases produced by it. Comminuted smokeless powder is ignited easily and burns, but is detonated most effectively not by a fuse, but by a No. 6 electric detonator. This powder proved to be sensitive both to percussion and friction; it is much less sensitive to percussion than 40 per cent. straight dynamite, is more sensitive than dry picric acid, and about as sensitive as nitroglycerin and gelatin dynamites. As to propulsive capacity, comminuted smokeless powder rated highest of explosives tested, except dry picric acid. The rate of detonation—which is the measure of its shattering power—was about six per cent. lower than the standard used, though it was the lowest for the explosives tested.

The full report (Serial No. 2386) on comminuted smokeless powder and its usefulness as a blasting agent may be obtained from the Director, U. S. Bureau of Mines.

TELLURIUM.

By H. A. Doerner.

FROM its chemical nature, tellurium is now known to be a non-metallic element belonging to the sulphur-oxygen group. It is most popularly known through its occurrence in certain gold ores—tellurides—which have been extensively mined in the Cripple Creek mining district, Colorado.

Tellurium is a silver-white solid with metallic lustre, the crystalline form being very brittle and easily powdered. It has a specific gravity of 6.27, melts at 452° C. and boils at red heat, giving off a golden-yellow vapor when air is excluded. When heated in air, tellurium burns with a blue flame tinged with green, and evolves white vapors of tellurium dioxide. An amorphous form of tellurium, obtained by reduction and precipitation from solution, has a specific gravity of 6.015, and when heated is changed to the crystalline variety. Tellurium is insoluble in water, carbon disulphide or hydrochloric acids, but it is dissolved by nitric acid or concentrated sulphuric acid. It does not tarnish in moist air, is resistant to alkaline solutions, except concentrated KOH, but it is dissolved by fused alkalies. Its atomic weight has been the subject of much controversy, but the value 127.5 has been generally accepted. The chemistry of tellurium is similar to that of sulphur. It forms three oxides: TeO, TeO_2, and TeO_3; also tellurides, tellurites, and tellurates. A number of halide compounds, a sulphide, and a sulphate are known.

The Bureau of Mines has compiled a brief report (Serial No. 2385) containing a summary of the known facts regarding tellurium, and reference to the published sources of information on the element.

FAILURE OF CENTRE SHOTS IN BLASTING.

By L. C. Ilsley, Electrical Engineer, and A. B. Hooker, Assistant Electrical Engineer.

IN blasting on a large scale with a blasting machine, trouble has been experienced with missed shots. The shots that fail to

fire are often a group in the centre of the series The Bureau of Mines has conducted field and laboratory tests to ascertain the cause and remedy of the difficulty. The results of the tests showed that if a large number of the common electric detonators are connected in series and fired where the earth is wet, a large leakage of firing current occurs, and the detonators at each end of the series circuit may fire, whereas the middle ones misfire. The detonators near the positive end fire because too little leakage has occurred to cause a misfire; those near the negative end will fire because enough current has returned to the circuit. The middle detonators misfire because the current is not sufficient to fire them before the firing of the end detonators has opened the circuit. The writers make recommendations as to the elimination of the misfiring of the centre shots. This report has been issued by the Bureau of Mines as Serial No. 2384, Reports of Investigations, which is available for distribution.

A Continuous Spectrum from Mercury Vapor. C. D. CHILD. (*Astrophys. J.*, May, 1922.)—From 1890 onward it has been known that mercury vapor can be made to emit a continuous spectrum. The conditions for such an effect are now described for the first time. They are three in number. The current density must be small, the temperature of the vapor must be above 120° C. and below a higher temperature depending on the density of the vapor, and, lastly, the vapor must have a density about the same as that of saturated vapor at 120° C. The best source of current for getting the continuous spectrum is a Wimshurst or Toepler-Holtz machine.

The metallic vapor that gives the continuous spectrum is not just the same as mercury vapor at room temperature, for it emits visible radiation without being ionized and, besides this, it has a lower ionizing potential.

"The carriers of the continuous spectrum are molecules of mercury while the atoms are the carriers of the line spectrum" is the opinion of the author. G. F. S.

From Zurich comes the announcement of the discovery of a new radioactive body. Piccard and Stahel have isolated it and given it the preliminary name UV. It takes 48 days to complete its half change into something else. It belongs in the actinium series. (*Physikal. Zeit.*, Jan. 1, 1922.) Four months later Otto Hahn publishes the results of his investigations, which he interprets as making the existence of UV impossible. No doubt the two Swiss savants will now proceed to do their utmost to establish the existence of their intellectual progeny, and the conflict of evidence will continue until the truth is known and recognized. G. F. S.

THE FRANKLIN INSTITUTE.

MEMBERSHIP NOTES.

CHANGES OF ADDRESS.

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Mr. Coleman Sellers, Jr., 1600 Hamilton Street, Philadelphia, Pennsylvania.
Mr. David H. Wilson, Jr., 253 Thirty-sixth Street, Brooklyn, New York.
Lieut. A. B. Wyckoff, Ontario, California.

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BOOK NOTICES.

DISCOURS ET MÉLANGES. Emile Picard, Permanent Secretary of the Academy of Sciences. 8vo, paper bound, 292 pages. Paris, Gauthier-Villars et Cie. Price, 10 francs, net.

This volume reminds one of Berthelot's "Science et Morale," being a collection of essays and addresses by the author, covering a wide range of subjects. There are biographies, essays on contemporary problems, notes on the history of science, pure and applied. Much of the book, of course, has a local value only, but several articles have a wider interest, among which we note one on the pretensions of Germany to a hegemony in science, another on anti-typhoid vaccination, and a third on the low birth-rate problem. In the last eight years, France has passed through a terrific crisis, and the feeling awakened by that experience must be reflected in its literature. One manifestation of this is the essay on the German claim to leadership in science. We all know of this, and the assertion should be especially galling to France, which, during the latter half of the eighteenth and first half of the nineteenth centuries, enjoyed, in almost all fields of science and philosophy, a leading part. It is, however, an ungracious task to discuss the relative values of the work of the scientists and philosophers of any age and time. As might be expected, Monsieur Picard gives but little acknowledgment to German workers. How far an appreciation of the service that England rendered at such great sacrifice awakens the passing compliments to inventors and discoverers born on the other side of "The Sleeve," cannot be determined, but extravagant claims are made for French work in almost all fields. A curious effort is made to trace the lack of real efficiency in German science to the nature of the language. No thoroughfare can be found in that direction. Each cultivated nation regards its language as the best adapted for the expression of thought, and it is hardly possible that one accustomed from infancy to a particular form can appreciate fully the value of another. English-speaking persons realize the advantage of the absence of distinctions of gender in ordinary nouns, and are much annoyed by the necessity of observing such distinctions in using the Continental tongues, yet those who are brought up in such distinctions consider them useful, although it must be noted that all recent suggestions of an artificial language, such as Volapük, Esperanto and Ido, avoid all distinctions of gender, except those belonging to actual sexes, and also avoid all modifications of the adjective in relation to the noun. Fichte claimed that German was a fundamental language, while

English is a hybrid, but there is no reason to regard his opinion as sound; it has pleased the Germans, and has been repeated by them of late years.

In his essay on the claims of Germany to a hegemony in science, our author is hardly thorough or entirely fair. He endeavors to place French work at the head of every list, an effort that was, of course, pleasing to his audience, and no doubt received with enthusiastic applause.

One of the essays worth special notice is that on aviation in France in 1909. An introduction dealing with the early history of aerial physics is given. Icarus is not mentioned, but Leonardo da Vinci is, and Montgolfier. The history of the development of the heavier-than-air machine is outlined, and while almost all those who have figured in the experimental work are mentioned, no reference is made to Langley. The omission can hardly be accidental, and it shows how narrow and prejudiced the French mind can be. The action is dastardly, and indicates that, however eminent M. Picard may be in the fields in which he labors, he lacks the judicial attitude that is an essential characteristic of science.

HENRY LEFFMANN.

UNITED STATES GEOLOGICAL SURVEY, Professional Paper No. 123, A Superpower System for the Region between Boston and Washington, by W. S. Murray and others. 261 pages, illustrations, plates, maps, quarto. Washington, Government Printing Office, 1921.

There is one very striking point on the title-page. It is the statement: "by W. S. Murray and others." It is common knowledge that important investigations require large staffs, but it is rare to see any one give credit to the "others" in the way that Mr. Murray does, both on the title-page and throughout the report.

The report is preceded by a full table of contents, and followed by a most excellent index, so that it is easily possible to locate any of the valuable information contained.

FOREWORD.

Dr. George Otis Smith, Director of the United States Geological Survey, has written a foreword in which he outlines the developments leading up to the survey and report. He shows how at Mr. Murray's instigation the matter was presented to the Secretary of the Interior and to Congress. This resulted in an appropriation by Congress of $125,000 for the fiscal year 1921 for the following purpose:

> For the survey of power production and distribution in the United States, including the study of methods for the further utilization of water-power, and the special investigation of the possible economy of fuel, labor, and materials resulting from the use in the Boston-Washington industrial region of a comprehensive system for the generation and distribution of electricity to transportation lines and industries, and the preparation of reports thereon.

The language of the act is so clear that it needs no further comment. The work was organized in July, 1920, under Mr. Murray and a special

staff of engineers. Regular members of the Department of the Interior also contributed actively to the work.

To supplement the detail work to be done by the engineering staff, an advisory board "consisting of men of vision and experience, representing our railroads, both steam and electric, and manufacturing, engineering and chemical industries," was appointed, which served without compensation.

The report was completed on schedule on June 30, 1921, was printed, and has only recently become available to the public.

SUMMARY REPORT.

Mr. Murray has condensed the report into the small space of sixteen pages. Following this are appendixes dealing with the details of the various sections.

It is not necessary to point out the great place that power has in modern industrial life. Mr. Murray has used the word "superpower" to "describe a system that would furnish power to the railroads and industries within the territory between Boston and Washington that has now become more familiarly known as the superpower zone." The system has become known as the superpower system. It is pointed out "first, that the economy in power production and distribution thus far attained has been due largely to the electric public utilities; second, that the failure to attain the highest possible economy has been due largely to restrictive policies that have inhibited the expansion of the electric public utilities." The plea is then made that this report, in showing the savings which may be made by the development of a larger system, may lead to the removal of present inhibitions.

Regardless of the detail organization, it is necessary that the several public utilities coöperate most closely in order to develop the fullest economy of our natural resources of coal and water-power.

SUMMARY OF CONCLUSIONS.

All data apply to the superpower zone, and for brevity this statement will be omitted in connection with the various figures given. The estimated requirement for energy supplied through the electric utilities for municipal, private and railroad purposes in 1930 is 31,000,000,000 kilowatt hours. The system proposed should supply this energy at an annual cost of $239,000,000, less than by uncoördinated systems. The total investment in the superpower system will be upwards of $1,100,000,000, of which slightly more than $400,000,000 will represent the values of existing facilities.

The saving to the manufacturing industrial establishments should be $190,000,000 in 1930 at the expense of an investment of $185,000,000 for motor equipment completely installed.

Within the superpower zone there are 36,000 miles of railroad measured as single track. Of this, 19,000 miles can profitably be electrified. The capital expenditure would be $570,000,000.

The actual saving in coal should be very great. In 1930, when the superpower system is completed, it should be 50,000,000 tons.

Various large present economical generating plants will be kept in service, whereas smaller uneconomical plants should be abandoned and provision made for the amortization of the investment.

It is suggested that the chronologic sequence for the construction of the superpower system be as follows:

Construction of steam plants in the anthracite region to use low-grade anthracite and supply power to this territory and to New York, Newark and Philadelphia.

The construction of hydro-electric plants on the Delaware and Susquehanna Rivers to supplement the above coal-burning plants.

The development of the Hudson River water-powers in the Adirondacks.

The construction of various steam plants at tide-water; and lastly,

The partial development of the Potomac River above Washington.

The water-power in this territory is comparatively small, and proper condensing water precludes further development of "mine-mouth plants" than are suggested above for the anthracite district.

For the long transmissions of large blocks of power the use of 220,000 volts is proposed. A lower voltage interconnecting network will also be necessary, and that proposed has been based on the use of 110,000 volts. The report gives many plates showing the plants and transmission lines proposed.

In the superpower zone there are now 558 electric-utility plants with an average capacity of 7900 K. W. The capacities of the superpower system plants proposed range from 60,000 to 300,000 K. W.

It is emphasized again that the superpower system is not to compete with the existing electric utilities. It is for the purpose of creating the fullest economy by coöperation of all electric utilities.

In determining the physical data on which the report and system were founded it was necessary to take the last year for which complete information was available. This was the year 1919. From the data for that and previous years the study was carried forward for ten years to 1930 to give time for the construction of the system and also to insure a design capable of caring for future growth.

The summary report is followed by thirteen appendixes dealing with electric utilities in independent operation in the superpower zone in 1919; proposed electrification of heavy traction railroads in the superpower zone; industry in the superpower zone; performance and cost of the superpower system and various other subjects relating to the problem.

The reading of this volume, "A Superpower System for the Region between Boston and Washington," should inspire any one to a greater appreciation of the necessities and possibilities of logical, technical determination of the future requirements of this great and growing industrial country.

H. GOODWIN, JR.

LABORATORY MANUAL OF PHYSICAL CHEMISTRY. By Albert W. Davison and Henry S. Van Klooster, Rensselaer Polytechnic Institute. 182 pages, illustrations, 8vo. New York, John Wiley and Sons, Incorporated, 1922.

The well-known technical institution with which the authors of this book are connected numbers among its graduates many men who have distinguished

themselves in the several departments of engineering. Its professors have been prominent in both research and teaching. Elderly chemists remember with pleasure Elderhorst's work on the blowpipe, so admirably adapted for the beginner in that department of analysis. The work before us is, as stated in the title, a laboratory manual only. It is assumed that before using it the student has been well instructed in the principles of physical chemistry, and the experiments selected are mainly with a view to their bearing on engineering applications. Very extensive references to the literature are made, for the general subject and for each experiment. Descriptions of apparatus are brief, inasmuch as such information can be obtained elsewhere. Blank pages and several pages of cross-section paper are included, for note-taking and records. Whether these inclusions are advisable is a matter of doubt. The use of them may oblige the student to keep the book upon the table on which the experiments are being conducted, and thus expose it to injury, though it is true that physical chemistry, as a rule, does not involve so much "mussiness" as the regular chemical course, especially the so-called "qualitative analysis" which is usual in college and school laboratories. The reviewer, however, regards separate note-books and cross-section sheets as better.

The book is the result of large experience on the part of the authors, and constitutes an excellent manual for instruction in the extensive, important and difficult field of physical chemistry. It is well printed in large, distinct type and the line illustrations are well drawn. There is no index, which seems to be a serious omission, although for the manner in which the book is to be used, namely, in regular succession of the several items, the index is less important than in a book of reference or of study.

HENRY LEFFMANN.

LA TELEFONIA A GRANDE DIZTANZA ED I REPETITORI TELFONICI. By Dott. Annibale Craveri e Comm. Sisto Demaldé. 416 pages, 124 illustrations, 16mo. Turin and Genoa. S. Lattes and Co., 1922. Price 24 lire, net.

Italy enjoys the honor of having among its long list of distinguished scientists several of those most famous in electrical discovery. The names of Volta and Galvani are written into the history of early research, and the former has his name immortalized by being given to an important electrical unit. In recent years the name of Marconi has become familiar over all the world. Under the spur of unity and the liberal government of the House of Savoy, Italy has acquired a high standing in all departments of science, politics, statesmanship, to supplement its long prominence in music, literature and art. The satiric remark of Metternich, that "it is not a country, but a geographical expression," no longer holds. The enormous extension that has taken place in the last few years in the application of electricity to the transmission of sound has been a spur to the making of many books. The work in hand is really, as we are informed in the preface, a second edition; although not so designated on the title-page. The first edition appeared in 1919, on the occasion of the first installation of certain apparatus in Italy. It is a well-printed, compact volume of convenient pocket size, neatly bound in green cloth with gold lettering, and contains, in its 416 pages of text and 124 illustrations, a comprehensive statement of the art and science in the field to which it is devoted. The

authors are familiar with the theory as well as the practice of the subject, being officers in the operative departments of the government lines. Frequent quotations from the literature of other countries show that they have not limited their studies to their own language. It is interesting to note the difference in the custom of the Italian language and English in treatment of proper names used as adjectives. English retains the capitalization, but most of the Continental languages do not. Hence, in this book we read of "linee pupinizzate" and "linee krarupizzate," which seem, to our standard, not to do full honor to Pupin and Krarup, but American chemists now frequently write "bunsen burner." The absence of an index is a serious defect of the book, but this is common in works printed on the Continent. In this case the defect is accentuated by the fact that a very scanty table of contents is provided. A good deal of attention is given to historical development of the subject, and to explanation of the principles involved, so that the book will be a great aid to the Italian student as well as to the practical worker. French scientific works are often praised for their clearness, but this book shows that Italian is capable of clear expression also. The truth is that every highly developed language is able to express all phases of thought of which the human mind is capable. Those persons who assert that some other language expresses thought better than English are simply not thoroughly familiar with the resources of the latter. HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 126, Aeronautic Instruments, Section II—Altitude Instruments, by A. H. Mears, H. B. Hendrickson and W. G. Brombacher. Sixty-four pages, illustrations, quarto. Washington, Government Printing Office, 1922.

This report, in four parts, covers the general field of altitude instruments and closely related subjects.

Part I, on altimeters and barographs, discusses briefly the subject of barometric altitude determination. A detailed description is given of the principal types of instruments used in England, France, Germany, Italy, Denmark and America.

Part II, on precision altimeter design, deals with the errors of altimeters in general and states the principles of design and some of the instances where more precise indications are required.

Part III, on statoscopes and rate of climb indicators, mentions the uses of these instruments and presents a detailed study of the various types and methods of testing used.

Part IV, on aerographic instruments, mentions the various mechanisms and devices used in thermograph construction and describes several typical instruments. Meteorographs of various types and strut thermometers, and their uses, are included.

Report No. 131, Aerial Navigation and Navigating Instruments, by H. N. Eaton. Forty-four pages, illustrations, quarto. Washington, Government Printing Office, 1922.

This work outlines briefly the methods of aerial navigation which have been evolved during the past years and describes the instruments used.

Dead reckoning, the most universal method of navigation, is first dis-

cussed. Then follows an outline of the principles of navigation by astronomical observation, a discussion of the practical use of natural horizons, such as sea, land, cloud, and haze in making sextant observations; the use of artificial horizons, including the bubble, pendulum, and gyroscopic types; and a description of the rapid methods and the special instruments which have been devised to expedite the reduction of observations and the plotting of position. Lastly, the comparatively recent development of the radio direction finder and its application to navigation are discussed.

Report No. 132, Recent Developments and Outstanding Problems, by Franklin L. Hunt. Ten pages, quarto. Washington, Government Printing Office, 1922.

This is the concluding number of a series of reports on aeronautic instruments and discusses briefly some of the more recent developments in aeronautic instrument design and mentions some of the outstanding problems.

The different types of instruments are discussed as far as possible in the order in which they are described in the preceding reports. Among the instruments considered are precision altimeters and barographs, a thermometric altimeter which automatically corrects for the effect of air temperature on altitude readings, rate of climb recorders, a combined statoscope and rate of climb indicator, low-speed air-speed indicators for lighter-than-air craft, ground-speed indicators, gyroscopic turn indicators, navigating instruments; also special investigations relating to the altitude effect of air-speed indicators, the properties of elastic diaphragms, Bourbon tubes and bimetallic bars and ink substitute for recording instruments.

Among the outstanding problems are mentioned the need of navigating instruments for long-distance flights and for flying at night and landing in fog, the improvement of oxygen instruments for high altitude flying, and the attainment of greater reliability and precision in all aeronautic instruments.

Report No. 148, The Pressure Distribution Over the Horizontal Tail Surfaces of an Airplane, III, by F. H. Norton and W. G. Brown. Twenty-five pages, illustrations, quarto. Washington, Government Printing Office, 1922.

The authors deal with the distribution of pressure during accelerated flight of the full-sized airplane, for the purpose of determining the magnitude of the tail and fuselage stresses in stunting.

As the pressures to be measured in accelerated flight change in value with great rapidity, it was found that the liquid manometer used in the first part of this investigation would not be at all suitable under these conditions; so it was necessary to design and construct a new manometer containing a large number of recording diaphragm gauges for these measurements. Sixty openings on the tail surfaces were connected to this manometer and continuous records of pressures for each pair of holes were taken during various manœuvres. There were also recorded, simultaneously with the pressures, the normal acceleration at the centre of gravity and the angular position of all the controls.

The present investigation consisted in measuring on a standard rigged JN4H airplane the distribution of pressure over the whole of the horizontal tail surfaces while the airplane was being put through manœuvres as violently as it was thought safe, including spinning and pulling out of dives.

PUBLICATIONS RECEIVED.

Discours et Mélanges par Émile Picard, Secrétaire Perpétuel de l'Academie des Sciences. 293 pages, 8vo. Paris, Gauthier-Villars et Cie., 1922. Price, paper, 10 Francs.

The Properties of Electrically Conducting Systems, including Electrolytes and Metals, by Charles A. Kraus, Professor of Chemistry in Clark University. American Chemical Society, Monograph Series. 415 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1922. Price, $4.50.

The Chemistry and Technology of Gelatine and Glue, by Robert Herman Bogue, M.S., Ph.D. 644 pages, 8vo. New York, McGraw-Hill Book Company, 1922.

Laboratory Manual of Physical Chemistry, by Albert W. Davison and Henry S. Van Klooster. 182 pages, illustrations, 8vo. New York, John Wiley and Sons, Inc., 1922.

La Telefonia a Grande Distanza ed i Ripetitori Telefonici: Dott-Annibale Craveri e Comm. Sisto Demaldè. 417 pages, illustrations, folding plates, 12mo. Torino, S. Lattes & C., 1922.

Lefax Radio Handbook, by J. H. Dellinger and L. E. Whittemore. 8 sections, unpaged, illustrations, 16mo. Philadelphia, Lefax, Inc., 1922.

U. S. Bureau of Mines: Bulletin 192, Carbon Black—Its Manufacture, Properties and Uses, by R. O. Neal and G. St. J. Perrott. 95 pages, 8vo. Technical Paper 277, Application of the Geophone to Mining Operations, by Alan Leighton. 33 pages, illustrations, plates, 8vo. Technical Paper 311, Factors in the Spontaneous Combustion of Coal, by O. P. Hood. 9 pages, 8vo. Washington, Government Printing Office, 1922.

National Advisory Committee for Aeronautics: Technical Notes, No. 88, Test of Oil-scraper Piston Ring and Piston Fitted with Oil-drain Holes, by H. S. McDewell. 10 pages, illustrations, quarto. No. 102, Skin Frictional Resistance of Plane Surfaces in Air. Abstract of Recent German Tests, with Notes, by W. S. Diehl. 4 pages, illustrations, quarto. No. 106, Notes on Aerodynamic Forces—III. The Aerodynamic Forces on Airships, by Max M. Munk. 8 pages, illustrations, quarto. No. 107, Structural Safety during Curved Flight, by Dr. Adolf Rohrbach. 18 pages, illustrations, plates, quarto. Washington, Committee, 1922.

Municipal Sanitary Precautions During Epidemic of Influenza: Rambling thoughts of a civil engineer, by Dr. Wm. Paul Gerhard, C.E. 8 pages, 8vo. Reprinted from *Municipal and County Engineering,* April and May, 1922. Price, 30 cents.

U. S. Bureau of the Census: Fourteenth census of the United States. Manufactures, 1919. Electrical Machinery Apparatus and Supplies. Engines, Locomotives and Aircraft. Prepared under the supervision of Eugene F. Hartley, Chief Statistician for Manufactures. 2 pamphlets, quarto. Washington, Government Printing Office, 1922.

CURRENT TOPICS.

Potency of Commercial Vitamine Preparations.—E. V. McCollum and Nina Simmonds, of Johns Hopkins University (*Jour. Am. Med. Asso.*, 1922, lxxviii, 1953–1957), have tested six commercial vitamine products for vitamine B. Young rats were used as experimental animals; they were given a restricted basal diet for several weeks, then received the same diet plus a commercial vitamine preparation for an additional period of several weeks. The growth curve of each rat was determined. The rats usually gained in weight but little if at all during the administration of the vitamine preparations. The deduction is made that the commercial preparations did not contain vitamine B in concentrated form, McCollum and Simmonds recommended that milk and leafy vegetables be used to supplement the deficiencies in the ordinary diet and to insure an adequate supply of vitamines. Salads should be eaten twice daily. A liberal helping of greens and a quart of milk or its equivalent in the form of manufactured dairy products should also be taken daily.

J. S. H.

Insecticidal Spraying from an Aeroplane. (*The Chemist and Druggist*, July 8, 1922, 38).—Publicity has been given in the daily press to an experiment carried out on a Kentish farm in spraying orchards from above, carrying the outfit in a swiftly moving aeroplane. We learn from Craven & Co., agricultural chemists, Evesham, that they were consulted by the farmer, who found that his 50-acre apple plantation was suffering from a visitation of green caterpillar. A 'plane from the Haviland Company was secured, and this was fitted with a specially made blowing appliance, by means of which the whole plantation was thoroughly treated in about half an hour. It is obviously impossible to treat thoroughly a plantation in half an hour by the most up-to-date appliances working from the ground. The experiment has aroused the greatest interest among fruit and hop growers all over the country.

R.

Use of Arsenotungstic Acid in Analytic Chemistry.—While many complex inorganic acids have been prepared by various investigators, uses have been found for comparatively few of these acids. Arseno-18-tungstic acid—hitherto without a use—has been applied for the colorimetric determination of uric acid by J. Lucien Morris and A. Garrard Macleod, of Western Reserve University (*Jour. Biol. Chem.*, 1922, l, 55–63). The uric acid is isolated from the sample as zinc urate, which is then dissolved in dilute hydrochloric acid. When this solution is treated with a solution of arseno-18-tungstic acid, a blue color develops, which is intensified if sodium cyanide also be present. A standard solution of uric acid in a phosphate buffer solution is also treated with arseno-18-tungstic acid and sodium cyanide. The color of the unknown is compared with that of the standard in a colorimeter; and the uric acid content of the unknown is calculated.

J. S. H.

Electrochemical Theory of Physiological Processes.—From a general consideration of the structure and arrangement of the central nervous system, laboratory observations of the electrochemical reactions of the organism, and clinical evidence, G. W. CRILE (*Proc. Am. Philosophical Soc.*, 1921, lx, 546–552) concludes that man is an electrochemical mechanism. The unit structure is a nerve-cell battery and its prolongation the nerve fibre which extends through the synapse or key to the muscle or gland. When an electric current flows from the nerve cell, it closes the synapse, completes the circuit, and causes the muscle or gland to act. Activity of the body and certain diseases decrease the potential difference between the two parts of the cell, its nucleus and its cell body. The nerve-cell batteries are discharged during consciousness, and are recharged during sleep.

J. S. H.

Gas in 1920. (*U. S. Geological Survey Press Notice.*)—Although the gas-making industry had great difficulty in obtaining adequate supplies of good fuel in 1920, the quantity of gas sold was greater than ever before, amounting to nearly 500 billion cubic feet, having a value of more than $300,000,000, according to the Geological Survey. The sale of by-products by gas-making companies was also greater in 1920 than in any previous year. Over 100,000,000 gallons of tar, 55,000,000 pounds of ammonium sulphate or its equivalent, and nearly 125,000,000 gallons of light oil and other derivatives were the principal items among these by-products.

The average price of gas in 1920 was much higher than it had been for several years, averaging 16 cents a thousand cubic feet greater for coal gas and water gas and 5 cents a thousand cubic feet greater for oil gas and coke-oven gas than in 1918.

R.

A Study of the Influence of the Suspension upon the Oscillation of a Pendulum. P. LE ROLLAND. (*Ann. de Physique*, March-April, 1922.)—In a bibliography of memoirs dealing with the pendulum, such for example, as that published by the French Physical Society, 200 pages long, there are surprisingly few dealing with the motion of the pendulum as a measurer of time. The greater number of them are concerned with the determination of the length of the seconds pendulum or with a study of the oscillation of the pendulum at different places. It is to the practical phase of the pendulum that the present author directs his energies, and in order that he may not be superficial he gives more than 200 pages to an investigation of the influence of the method of suspension. By using the photographic method he is able to compare to the one millionth part the periods of two pendulums using no longer than three minutes for the actual swing. From this time onward his investigation must be known and quoted.

G. F. S.

Chemicals from Corn Cobs.—By developing new methods of extracting furfural from corn cobs, chemists of the United States Department of Agriculture have greatly reduced the cost of making this chemical, which is used in the manufacture of soluble and insoluble resins for stains, varnishes, insulating material, printing plates, and many other articles. Furfural has been made commercially from oat hulls and has been selling for about 50 cents a pound, but when made from cobs it is estimated that it can be manufactured at a cost of about 10 cents a pound. Cobs give the greatest yield of furfural of any of the common agricultural materials that contain it.

R.

Toxicity of Germanium.—The rare element germanium lies next to arsenic in the periodic system. The relative toxicity of these two elements is therefore a matter of interest. F. S. HAMMETT, J. H. MULLER, and J. E. MOWREY, JR., of the University of Pennsylvania (*Jour. Pharm. and Exp. Therapeutics*, 1922, xix, 337–342), have studied the relative toxicity of germanium dioxide and arsenious oxide when administered subcutaneously to albino rats. Arsenious oxide usually produced fatal results when given in a dose of 8 millegrams per kilogram of body weight; sublethal doses caused sloughing at the point of injection. Germanium dioxide in doses as great as 180 millegrams per kilogram of body weight produced neither death nor any apparent evidences of harmful effect; sloughing did not occur at the point of injection. With respect to toxicity, germanium resembles the tin group rather than the arsenic group of elements.

J. S. H.

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